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Microsoft Teams (online)
Item 3 of the provisional agenda

Programme Performance Report of the
United Nations Environment Programme for 2024

The second draft of UNEP's Global Environmental Data Strategy (GEDS) has been developed by the Secretariat based on feedback received on the first draft.

The revised draft reflects inputs from consultations held between October 2024 and July 2025 and outlines a more action-oriented framework, focused on nine targeted intervention points and associated implementation and funding mechanisms.

It also serves as a complement to the overview of the GEDS as set out in document UNEP/CPR/ASC/12/2.

Executive summary

The Global Environmental Data Strategy (GEDS) offers a practical framework to improve how environmental data is produced, governed and used worldwide. In an era of accelerating climate change, biodiversity loss and pollution, decision-makers depend on timely and reliable data. In practice, however, data are often fragmented, inaccessible or lacking altogether. GEDS sets out a targeted agenda to tackle these challenges and deliver the coordination, prioritization and investment needed for effective global environmental governance.

Mandate and vision

GEDS was developed in response to UNEA resolution 4/23, requesting UNEP to develop a long-term strategy for environmental data "in consultation with Governments, United Nations agencies, funds and programmes, the secretariats of the multilateral environmental agreements (MEAs) and international and regional scientific bodies". This mandate reflects a recognition that no single institution can deliver this transformation alone – but also that UNEP has a key role as a trusted convener, a steward of science-policy knowledge, and a developer of frameworks and tools that enable action by others.

GEDS articulates a shared vision that:

> *By 2035, the world has a trusted, inclusive, accessible and interoperable environmental data ecosystem that enables collective action at the speed and scale needed to solve the triple planetary crisis and support sustainable economies and societies worldwide.*

Achieving that vision will require sustained and coordinated action from many actors, including governments, regional institutions, the private sector, academia and civil society. GEDS supports this collective effort by fostering shared understanding of the broad landscape of challenges and potential responses, while also narrowing the focus to practical priorities. In doing so, it aims to guide investment and help align the many actors already working to improve the global environmental data ecosystem.

Building foundational understanding

GEDS is grounded in several years of analytical work and consultation. As summarized in Chapter 1, UNEP reviewed existing environmental data platforms, standards and statistical capacities; compiled an inventory of more than 800 existing initiatives; mapped data standards; developed a roadmap on environment statistics and analysis; and gathered feedback through multiple international forums. Collectively these efforts built a clearer picture of system-wide gaps, opportunities and entry points for improvement. They culminated in the identification of five core pillars of a well-functioning environmental data ecosystem, which serve as the analytical backbone for the strategy: governance, quality and provenance, interoperability, access and affordability, and capacity-building.

In 2024-2025, UNEP conducted wide-ranging consultations with Member States and other stakeholders to deepen understanding of the specific challenges and needs within each pillar. This process helped to validate the framework and shaped the strategy's content and structure.

From challenges to targeted action

The GEDS consultation process surfaced a wide array of challenges and emerging responses across the global environmental data ecosystem. Chapter 2 synthesizes these insights, organized around the five pillars, and Annex III explores them in greater detail. This body of evidence provides the analytical foundation for the strategy (Figure 0.1).

Chapter 3 distils that complexity into eight strategic intervention points – concrete areas where targeted and coordinated action can strengthen the global environmental data ecosystem:

1. National environmental data strategies
2. Data quality assurance
3. Essential variables and scientific standards
4. Interoperability standards
5. Product sustainability disclosures
6. Federated platforms and data sovereignty
7. Access to priority datasets
8. Capacity development

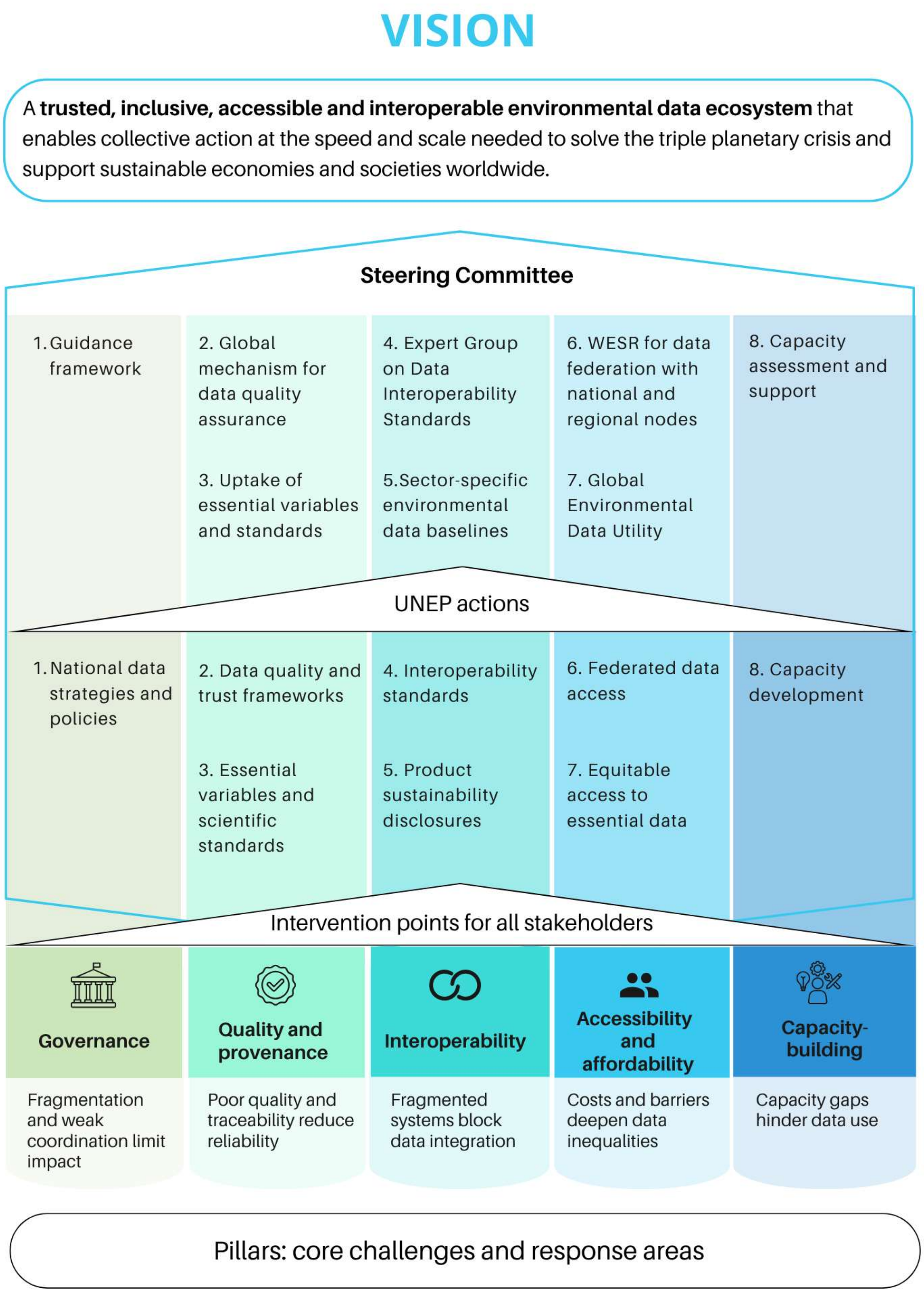
For each of these intervention points, GEDS identifies a specific enabling action where UNEP can play a catalytic role by convening actors and developing frameworks, tools and guidance to support implementation. These proposed UNEP contributions are intended to inform dialogue with Member States and guide resource mobilization efforts. Since many of UNEP's proposed contributions involve the creation of tools, frameworks and platforms to be implemented by others, their impact will depend on active piloting and uptake by Member States and other partners.

Chapter 4 briefly outlines an implementation approach for GEDS, aimed at enabling coordinated delivery by UNEP and its partners. Annex I elaborates this further, providing a more detailed outline of the activities and costs, distinguishing between UNEP's contributions and broader implementation measures led by other stakeholders. It also presents proposals for a stakeholder-led implementation model and pooled funding mechanism, capable of coordinating and resourcing delivery in an agile and adaptive way.

Looking ahead

GEDS is not a blueprint for a single institution but a practical, stakeholder-driven roadmap for concerted action, based on wide-ranging consultations with Member States and other partners. It provides a common reference point for aligning efforts, guiding investments and strengthening efforts to transform the global environmental data ecosystem. Realizing this vision will depend on strong political will, coordinated action across institutions and sectors, and sustained investment over time. UNEP's proposed contributions offer a practical and catalytic starting point. But their success will ultimately depend on deep collaboration and shared commitment from the wider international community.

Figure 0.1 Realizing the GEDS vision: from challenges to targeted actions



Contents

List of acronyms

Acronym	Definition
AGROVOC	Agricultural Vocabulary (FAO's controlled vocabulary)
AI	Artificial Intelligence
API	Application Programming Interface
ARD	Analysis Ready Data
CARE	Collective Benefit, Authority to Control, Responsibility, and Ethics (Indigenous data governance principles)
CDIF	Common Data Interchange Format
CEFACT	Centre for Trade Facilitation and Electronic Business (part of UNECE)
CODATA	Committee on Data of the International Science Council
COG	Cloud Optimized GeoTIFF
CWL	Common Workflow Language
DCAT	Data Catalog Vocabulary (W3C standard)
DDI	Data Documentation Initiative
DOI	Digital Object Identifier
EO	Earth Observation
EOSG	Executive Office of the Secretary-General (UN)
ENVO	Environment Ontology
ESG	Environmental, social and governance
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable (data principles)
FAO	Food and Agriculture Organization of the United Nations
FPIC	Free, Prior and Informed Consent
GBIF	Global Biodiversity Information Facility
GCMD	Global Change Master Directory (NASA vocabulary)
GDC	Global Digital Compact
GEDS	Global Environmental Data Strategy
GEO	Group on Earth Observations
GIZ	German Development Agency
GLAD	Global Land Analysis and Discovery
GLAM	Global Life Cycle Impact Assessment Method
ICT	Information and Communication Technology
IoT	Internet of Things
ISO	International Organization for Standardization

ITU	International Telecommunication Union
JSON	JavaScript Object Notation
LCA	Life Cycle Assessment
MEA	Multilateral Environmental Agreement
MQTT	Message Queuing Telemetry Transport
NGO	Non-governmental organization
OASIS	Organization for the Advancement of Structured Information Standards
OBIS	Ocean Biodiversity Information System
ODIS	Ocean Data and Information System
OGC	Open Geospatial Consortium
ORCID	Open Researcher and Contributor ID
OWL	Web Ontology Language
PROV	Provenance Ontology (W3C standard)
QA/QC	Quality Assurance and Quality Control
QGIS	Quantum Geographic Information System
RDF	Resource Description Framework
SDG	Sustainable Development Goal
SDMX	Statistical Data and Metadata Exchange
SKOS	Simple Knowledge Organization System
SPARQL	SPARQL Protocol and RDF Query Language
STAC	SpatioTemporal Asset Catalog
TNFD	Taskforce on Nature-related Financial Disclosures
TRUST	Transparency, Responsibility, User focus, Sustainability, and Technology (data principles)
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGIS	United Nations Group on the Information Society
UNODC	United Nations Office on Drugs and Crime
UNSG	United Nations Secretary-General
WDL	World Digital Library
W3C	World Wide Web Consortium
WESR	World Environment Situation Room
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

1 Context and strategic foundations

1.1 The need for a Global Environmental Data Strategy (GEDS)

The world today faces rapidly growing and interconnected environmental crises. Innovative digital solutions coupled with artificial intelligence (AI), powered by diverse sources of data, are emerging as powerful resources to address these acute challenges. In some environmental domains and regions, efforts are under way to create more harmonized environmental data ecosystems, offering more broadly useable data products and services. Yet, major barriers remain. The global environmental data ecosystem is deeply fragmented, with a proliferation of platforms, data types and metrics that are often not interoperable. Merging and using such diverse data can be technically and institutionally difficult, while physical, financial and capacity-related barriers further limit access. This fragmentation has important impacts. According to the Executive Office of the UN Secretary-General, for example, "Progress towards achieving 41 per cent of the 92 environmental Sustainable Development Goals indicators ... cannot currently be globally measured owing to a lack of interoperable data and standardized reporting." (UNSG, 2023).

Many governments are already taking steps to drive forward digital transformation in their countries. But isolated actions will not be enough to create an effective global environmental data ecosystem. Environmental problems are often highly interconnected and transboundary in nature, transcending both geographic borders and domains such as environment, health and economy. Addressing challenges of this sort requires coordinated action at all scales to achieve results. Moreover, coordination is made difficult by the distinctive characteristics of environmental data (Jensen and Nachmany, 2020). These include the complexity of geospatial data, which creates huge demands for data storage and processing, and major ethical and security concerns linked to collecting and sharing data about ecosystems and natural resources, which can make data exchange very difficult.

UNEA resolution 4/23: the mandate for GEDS

Recognizing the need for stronger global action on environmental data governance, the United Nations Environmental Assembly (UNEA) adopted resolution 4/23, requesting the United Nations Environment Programme (UNEP) to develop and prioritize a long-term data strategy "in consultation with Governments, United Nations agencies, funds and programmes, the secretariats of the multilateral environmental agreements (MEAs) and international and regional scientific bodies, with particular attention to regular regional and global analysis of the state of and trends in environmental parameters as a basis for, inter alia, the future Global Environment Outlook process" (UNEP, 2019b). The Ministerial declaration adopted during UNEA 4 also stated that the world's ministers of environment will "support the United Nations Environment Programme in developing a global environmental data strategy by 2025 in cooperation with other relevant United Nations bodies" (UNEP, 2019a).

GEDS has been developed within the context of UNEP's broader activities promoting digital transformation, which include action to advance data analytics, cloud computing and AI in order to strengthen environmental data analysis and application. These strategic priorities are taken up in the UNEP Medium-Term Strategy 2022–2025 (UNEP, 2021) and the UNEP programmes of work 2022-2023 and

2024–2025 (UNEP, 2023), which together aim to ensure that environmental assessments, monitoring, reporting and decision-making are supported by robust, accessible and reliable data. GEDS has also been prepared with reference to the UN Secretary-General's Data Strategy (UNSG, 2020) and the Global Digital Compact, and in coordination with the international data governance work of the UN's High-Level Committee on Programmes (UN, 2023) and the data and digital strategies being developed by partner organizations and initiatives, including the various multilateral environmental agreements.

Box 1.1 The context for GEDS: a rapidly evolving data landscape

The development and future implementation of GEDS is taking place in a fast-changing context. Shifts in technology, business models and user expectations are transforming the global environmental data ecosystem and exposing major governance gaps.

- **Expanding data sources:** Drones, sensors, edge computing, smartphones, the Internet of Things and citizen science are dramatically expanding the volume and variety of environmental data, enabling localized insights at scale. But major challenges in managing, integrating and validating data.
- **Changing expectations:** Users increasingly expect fast, intuitive platforms that deliver actionable insights in real time. Platforms increasingly offer customizable interfaces, access to data and human-centred design.
- **Platform proliferation and fragmentation**: New platforms are emerging fast, often driven by evolving user needs, siloed initiatives and uncoordinated funding. This has created a scattered digital landscape, with outdated or incompatible platforms contributing to "data islands", user fatigue and duplication of effort.
- **Sectoral integration:** environmental data are increasingly embedded in economic and social domains, from national accounting to financial disclosures. New tools are needed to help users integrate diverse sources.
- **Loss of credibility and trust:** Surging connectivity makes it hard to identify credible data sources. Misinformation spreads rapidly through echo chambers and filter bubbles, undermining trust.
- **The rise of AI:** Artificial intelligence offers vast new potential for modelling, analysis and real-time decision support but raises concerns around bias, reliability, transparency and energy use.
- **Structural shifts and power imbalances:** Data systems are becoming more decentralized and interoperable, while digital power is increasingly concentrated in a few large tech companies. This reinforces the need for effective public-private collaboration.
- **Principles for ethical governance:** There is growing momentum for creating a more fair, inclusive and sustainable data ecosystem. Frameworks such as FAIR, CARE and TRUST are shaping best practice, while concerns about data's environmental footprint are driving advances in green data infrastructure.

1.2 Development of GEDS: vision, process and structure

Guiding vision and principles

The GEDS vision is that, by 2035, the world has:

A trusted, inclusive, accessible and interoperable environmental data ecosystem that enables collective action at the speed and scale needed to solve the triple planetary crisis and support sustainable economies and societies worldwide.

In developing and implementing a strategy to help realize this vision, the emphasis has to be on understanding the realities and needs of different stakeholders, and finding ways to align incentives around shared solutions. In practice, this means acknowledging issues like the deep digital divides that exist between and within countries and communities, and also guaranteeing that countries can retain control over their own data, including deciding what is shared and who has access.

GEDS sets out a **flexible and voluntary framework** to guide the development of more focused strategies and programmes by UNEP and its partners at international and national levels. **It does not introduce any new reporting requirements or legal obligations for Member States.** Nor does it position UNEP as the central repository or manager of all environmental data or as a lead implementer at country level. Rather UNEP's role is rooted in its core strengths: as a trusted convenor of stakeholders, a facilitator of science-policy dialogue and a developer of globally applicable frameworks and tools that can be taken up and adapted by Member States and other partners.

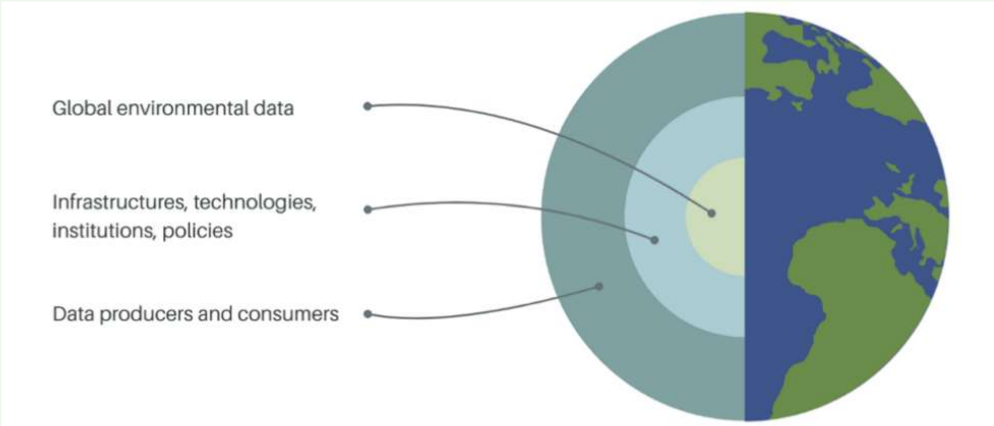
GEDS provides a blueprint to help Member States improve how environmental data are managed, shared and used, supporting the development of distributed, federated data repositories that are mandated and controlled by Member States, and underpinned by national monitoring systems led by ministries or government agencies. While GEDS does not propose to develop and impose new data formats, standards and protocols but it could trigger global action to harmonize and simplify the fragmented patchwork that exists today. Finally, GEDS aims to support, connect and build on existing global, regional and domain-specific data governance frameworks – including those under multilateral environmental agreements (MEAs) – rather than overriding or replacing them.

In this sense, GEDS is not a prescriptive strategy but a collaborative effort to align and strengthen existing initiatives. It respects national priorities and promoting data sovereignty, while offering tools, principles and options that countries, institutions and communities can choose to adopt, adapt or build upon, with or without UNEP involvement. In this spirit, the priority action areas outlined in Chapter 3 point to the potential roles of a wide range of stakeholders, while also identifying potential ways that UNEP could be mandated to play a catalytic role in supporting system-wide change.

Box 1.2 Key definitions

GEDS aims to strengthen the way that environmental data are produced, shared and used across all levels of governance. Its scope covers the **global environmental data ecosystem**: the interconnected network of actors, systems, standards, technologies and practices involved in collecting, managing, sharing and using environmental data across local, national, regional and global levels. This includes public institutions, private sector entities, academic bodies, civil society and Indigenous communities., as well as the digital infrastructure, governance frameworks and ethical norms that enable data to inform environmental monitoring, decision-making, reporting and action. (**Error! Reference source not found.**).

Figure 1.1 The global environmental data ecosystem



Environmental data are defined as:

> *Environmental data are formally structured values or other representations that describe the state of the environment, the human and natural drivers and pressures causing environmental change, the resulting impacts on people and ecosystems, and the characteristics and effectiveness of societal responses.*

Substantively, environmental data encompass the broad range of themes that follow from the driver-pressure-state-impact-response (DPSIR) chain, structured vocabularies such as the General Multilingual Environmental Thesaurus (GEMET) and global frameworks such as the Sustainable Development Goals (SDGs). These include data on socio-economic and demographic drivers of environmental change; sectoral and business-level activities; resource use and harmful emissions; land use and ecosystems; water and oceans; impacts on people and ecosystems; disaster risks and resilience; policy and governance; and innovation, technologies and social change.

As outlined briefly in Annex IV, environmental data are generated using a wide range of measurement techniques and presented in diverse format. Key sources include Earth observation, drones, Internet of things (IoT) sensors, ground monitoring stations, academic research, corporate disclosures, crowdsourcing, communities and Indigenous groups, and citizen science. The emergence of advanced AI models is also creating new opportunities to infer data to fill gaps.

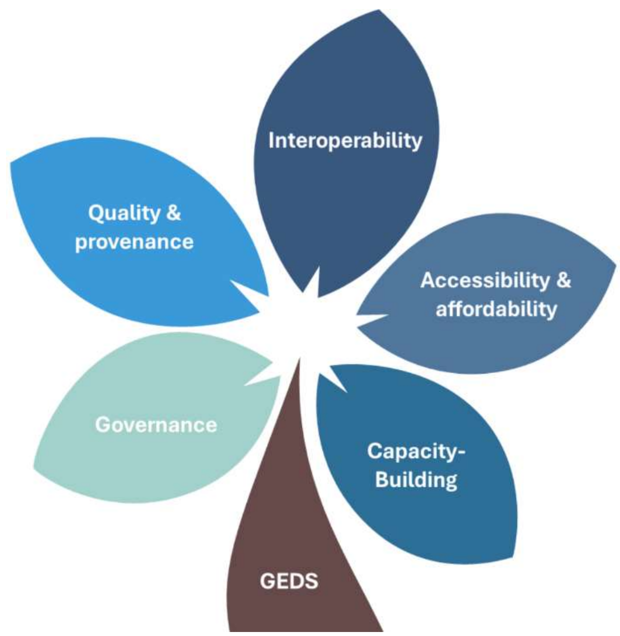
For monitoring, reporting and policymaking purposes, national governments typically recognize only a subset of these sources, which have been vetted and validated by their national statistical agencies or their equivalents.

Process and structure

Since 2020, UNEP has undertaken considerable work to develop GEDS. This includes investing in a series of reports and ad hoc multi-stakeholder consultation processes aimed at building a deep understanding of the global environmental data ecosystem, including existing platforms, data sources and standards. As set out in more detail in Annex II, the analytical work has included developing a UNEP roadmap on environment statistics, accounting and analysis (2021); a preliminary mapping of existing environmental data standards globally (2023); and an inventory of more than 800 external environmental data platforms. Preliminary stakeholder engagement and feedback sessions were also hosted in multiple forums.

The background work culminated in the identification of five key focal areas that reflect the essential conditions for producing and using environmental data that are scientifically robust, ethically governed and fit for purpose. This starts with the need for rigorous measurement and traceability of environmental parameters, and extends to issues of interoperability, access and long-term capacity. These areas are:

- **Governance:** The framework of policies, institutions, principles, roles and practices that underpin the other pillars, supporting ethical, effective and sustainable environmental data management.
- **Quality and provenance:** Tools and processes to ensure that data circulating through the global environmental data ecosystem are traceable, validated and fit for purpose.
- **Data interoperability**: Alignment of data systems and exchange standards to support discovery, observability, and further processing of data across ecosystem partners with minimal transformation.
- **Data access and affordability**: Actions to ensure that all stakeholders can access and afford the environmental data that they need, while also addressing concerns about sensitive data and security.
- **Capacity-building**: Measures to help countries and other stakeholders develop the skills, knowledge, technologies and infrastructures that are needed to collect, process, share, communicate and use data effectively.



In 2024, UNEP undertook a wide-ranging consultation process in each region with UN Member States and other stakeholders, which aimed to build a shared understanding of the core challenges that they face in each of the five focal areas and the responses needed to achieve the GEDS vision. Chapter 2 of GEDS provides an overview of the insights gathered during the consultation, which are set out in extensive detail in Annex III.

Chapter 3 builds on this analytical foundation, identifying eight intervention points where coordinated actions by different stakeholder could drive significant progress toward the 2035 vision. These include a set of actions that UNEP could implement to catalyse change in each area.

Chapter 4 summarizes the UNEP actions and indicative budgets for the period 2026-2035, and briefly outlines a potential implementation model and financing mechanism. Annex I provides more detail on each of these elements.

2 The case for action: understanding the challenges and needed responses

This chapter provides a high-level synthesis of the core challenges and response areas identified through the GEDS consultation process and supporting research, organized around five interlinked pillars: governance, data quality and provenance, interoperability, accessibility and affordability, and capacity-building.

The insights presented here are explored in much greater detail in Annex III. Rather than presenting a definitive list of actions, this chapter maps the broad landscape of needs and opportunities across the environmental data ecosystem. The actions outlined at the end of each section are not proposed mandates for UNEP. Instead, they describe the types of efforts that will be needed from a wide range of stakeholders – governments, international organizations, private sector actors, Indigenous groups and others – often working in different combinations, to realize the GEDS vision. This mapping exercise illustrates the scale and complexity of the challenges ahead. It also provides the analytical foundation for the eight strategic intervention points proposed in Chapter 3, where coordinated efforts by UNEP and its partners could unlock significant progress.

2.1 Pillar I: Governance

Scope and vision

The data governance pillar encompasses the collective framework of policies, institutional actors, practices, principles (at both national and international levels), which ensure that environmental data are accessible, interoperable, secure, good quality and contribute to effective policymaking and action.

In the data governance context, **achieving GEDS vision would imply that in 2035, global environmental data governance is coordinated and transparent, guaranteeing data sovereignty while enabling effective collaboration across borders and sectors.** Governance principles and practices would be inclusive and equitable, empowering vulnerable communities and fostering secure, ethical and transparent data use. They would uphold data ownership rights, including for Indigenous Peoples and local communities, ensuring clarity over who controls, accesses and benefits from environmental data. They would also be responsive to the needs of all stakeholders to make data-driven decisions to support sustainable development. Critical indicators would be prioritized and environmental data would be routinely and verifiably integrated into policy and business strategies for a resilient future.

Challenges

Effective environmental data governance is foundational to advancing sustainability, yet it faces systemic challenges across national, regional and global levels. A foundational concern is guaranteeing **data sovereignty and security**. Governments, Indigenous groups and other communities have legitimate rights over data related to their territories, resources, intellectual property and knowledge that must be respected. However, overly restrictive approaches may hinder global environmental action. This tension is compounded by risks of data colonialism, where powerful actors extract data from less developed regions without fair sharing of benefits. Unclear ownership rights and lack of transparency in data governance further undermine trust and equitable participation. Cybersecurity threats further erode confidence in data-sharing platforms, while the absence of clear data classification systems makes it hard to identify and manage sensitive datasets, undermining collaboration and trust.

At the national level, many countries struggle with **uncoordinated data management**. Environmental data are often siloed across ministries and agencies, with weak coordination, outdated standards and low political prioritization. National statistical offices may lack clear mandates, while legal or commercial constraints limit access. The absence of national data strategies prevents coherent governance, while public–private interdependence is often neglected, despite the increasing role of business in both consuming and generating environmental data.

Globally, **fragmentation across environmental domains and governance scales** limits data integration. Platforms and networks remain sector-specific and disconnected, while there would be advantages in aligning some MEA reporting cycles, format and standards. Recent progress under biodiversity-related MEAs, such as synchronized reporting cycles, common indicators and modular digital tools, offers a model for integration in other areas.

Structural **inequities and power imbalances** also shape who participates in governance and whose knowledge counts. Many developing countries and Indigenous communities face barriers to accessing data, participating in governance processes or ensuring their knowledge is respected. Global datasets and assessments often reflect the perspectives and research of high-income regions, limiting the visibility of others. Unfair data-sharing practices and bias in AI systems risk reinforcing these disparities.

Securing the **long-term availability and integrity of data across regions** is also a key concern. Data in individual jurisdictions can be lost through policy changes, cyberattack, natural disaster or other internal and external threats. Thus, governance mechanisms to facilitate secure mirroring and cross-archiving of key digital assets with trusted ecosystem partners in different regions must be established and maintained.

Finally, the data ecosystem is increasingly burdened by **data overload and inefficiency**. The proliferation of datasets, indicators and reporting demands create high costs, especially in managing spatial data and meeting obligations. Much data lacks clear purpose or standards, leading to needless duplication and underuse. Without improved stewardship, prioritization and infrastructure, the environmental data ecosystem risks becoming unsustainable, excluding the very actors it aims to serve.

System-wide responses

Focus area	Key actions
Guaranteeing data sovereignty and security	• Establish national legal frameworks to govern data access, sharing, deletion and privacy. • Develop federated governance models that enable collaboration while respecting national control.

	• Uphold Indigenous data sovereignty through co-designed governance protocols, Free, Prior and Informed Consent (FPIC) and reciprocal benefit-sharing. • Promote cybersecurity by adopting secure digital infrastructures and international security standards. • Develop and implement national data classification schemes to clearly distinguish between public, restricted and confidential environmental data, enabling secure and appropriate data sharing. • Support the implementation of data enclaves and/or Data as a Service (DaaS) architectures, to allow analytics to be performed on obfuscated and localized data stores.
Strengthening national environmental data management	• Develop national environmental data strategies or integrate environmental provisions into broader national data policies, embedding the FAIR (Findable, Accessible, Interoperable, Reusable), TRUST (Transparency, Responsibility, User focus, Sustainability and Technology), CARE (Collective benefit, Authority to control, Responsibility and Ethics) and openness principles. • Further promote openness by adopting open licenses, machine-readable and machine-actionable formats and open-source tools. • Integrate business and consumer needs into national strategies by identifying priority datasets of shared value and establishing coordination mechanisms that engage relevant stakeholders. • Operationalize national data strategies by requiring relevant large-scale projects to develop machine-readable and machine-actionable data management plans. • Incorporate citizen science into national environmental data strategies, recognizing its value in gap-filling, cost-effectiveness and community engagement.
Coordinating global environmental data governance	• Connect and align domain-specific, regional and geospatial platforms by mapping interdependencies and developing shared indicators. • Support further harmonization of MEA reporting by aligning indicator definitions, technical specifications, reporting cycles and geospatial data structures, and making data accessible through interoperable platforms. • Support alignment between corporate disclosures and global indicator frameworks by promoting interoperable standards and shared platforms. • Invest in national monitoring systems and data infrastructures, leveraging global funding and technical assistance to enhance country-level capabilities.
Tackling inequities, power imbalances and ethical issues	• Ensure inclusive participation in governance by engaging Indigenous and marginalized voices at all levels and investing in capacity-building. • Empower non-governmental organizations (NGOs) as data intermediaries and ensure they have equitable access to environmental data platforms.

	• Mainstream gender through sex-disaggregated data, gender-sensitive indicators and targeted support for inclusive environmental statistics. • Promote open data and open science to strengthen public engagement and evidence-based decision-making. • Clarify and uphold data ownership through co-developed frameworks that ensure transparency over access, control and benefit-sharing. • Ensure AI use is transparent, inclusive and ethical, with appropriate training data and shared frameworks to prevent bias and exclusion, and supported by practical guidance to align with UN principles on responsible AI.
Ensuring effective data stewardship and managing data overload	• Identify and prioritize high-value datasets and variables to streamline reporting and reduce redundancy. • Promote efficient, low-carbon data infrastructure and federated systems that support interoperability while managing environmental impact.

2.2 Pillar II: Quality and provenance

Scope and vision

The data quality and provenance pillar focuses on the tools and approaches needed to ensure that the global environmental data ecosystem produces the data needed by governments, businesses and other stakeholders, and that these data meet relevant quality criteria. As such, this pillar takes a broad view of data quality, encompassing not only technical characteristics such as accuracy and consistency, but also availability and relevance to user needs. The topic of data quality and provenance is closely tied to issues of accessibility, interoperability and capacity-building, which are further elaborated in Pillars III, IV and V.

In the data quality and provenance context, **achieving GEDS vision would imply that in 2035, we have a global environmental data ecosystem that delivers data that are accurate, consistent and fit for purpose, based on robust and transparent processes and validation protocols, and comprehensive metadata.** Good quality data empower decision-makers with trustworthy and explainable insights, bridging the gap between global and local data needs. Collectively, quality control, quality assurance and complete provenance tracking will create a data ecosystem that fosters confidence in environmental datasets, enabling informed, equitable and sustainable actions worldwide.

Challenges

Persistent **gaps, inaccuracies, obscure lineage and biases in environmental datasets** undermine sound decision-making. Many regions lack consistent monitoring and global models are skewed toward well-documented ecosystems and developed countries. Data are often outdated, incomplete or insufficiently disaggregated for local use. ESG and product-level disclosures remain uneven, especially among smaller firms and in low-income regions. Citizen science is increasingly recognized as a credible and cost-effective data source in national and international frameworks, particularly for biodiversity, but its uptake is often limited by uncertainties around standardization, data validation and uneven spatial or temporal coverage.

These issues are compounded by **weak or inconsistent standards for data collection, processing and quality assurance**. Diverse sampling methods, instruments and processing approaches are often used without intercalibration or reference to a clear quality management framework, limiting comparability and integration. Remote sensing and modelled data introduce additional variation, as they often rely on different methods and quality standards than in-situ measurements. Few systems maintain publicly accessible, machine-readable registers of data quality measures, which can help ensure that standards are consistently observed and verifiable. Product-level data, such as lifecycle assessments and carbon footprints, often rely on differing assumptions and lack standard validation. While frameworks like ISO 8000 or SDMX exist, adoption is uneven, partly due to the high cost and complexity of compliance, and data quality requirements vary widely by use case.

Limited transparency and data provenance further reduce trust. Many datasets lack comprehensive metadata or lineage documentation, making it hard to verify their origins and how they were handled. The growing use of AI approaches often introduces additional opacity and reduces trustworthiness, especially when model logic and training data are not disclosed. Traceability challenges also affect corporate sustainability data, where environmental impacts embedded in supply chains are difficult to track.

These weaknesses contribute to a **broader loss of confidence in environmental data systems**. The lack of robust verification, particularly for corporate claims, enables greenwashing, while the exclusion of Indigenous and local knowledge undermines legitimacy and completeness.

Environmental data often remain **misaligned with decision-making needs**. Academic datasets subject to peer review may be inaccessible or impractical; Earth observation (EO) data are often insufficiently tailored to national priorities; and corporate disclosures may be too general. Compatibility and integration of data across environmental, social and economic domains is limited, **constraining the ability to conduct systemic sustainability assessments** and inform holistic policy responses. In many cases, data collection proceeds without clearly defined use cases or decision targets, leading to wasted effort.

System-wide responses

Focus area	Key actions
Addressing gaps, inaccuracy and biases in environmental datasets	• Implement routine data profiling and audit mechanisms at national and international levels. • Promote structured bias detection tools adapted from other domains (e.g. UNODC) for use in environmental data. • Use advanced technologies such as AI to augment quality control, anomaly detection and data harmonization across sources. • Expand access to Earth observation data and strengthen international data-sharing partnerships. • Apply triangulation and data fusion techniques to integrate satellite, in situ and citizen science data. • Develop protocols for using modelled outputs or global datasets when national data are missing.

	• Establish publicly accessible, machine-readable registers of data quality measures to improve transparency and consistent quality standards.
Strengthening standards on data collection, processing and QA	• Map and co-develop global minimum standards for scientific data collection, uncertainty reporting and analysis methods. • Develop and enforce calibration and testing protocols for environmental sensors, especially low-cost monitors, alongside reporting of results in provenance metadata. • Harmonize ESG reporting and product-level disclosure standards internationally. • Compile existing QA/QC guides and promote their uptake through national protocols and international validation hubs. • Operationalize data quality frameworks (e.g. ISO 8000) through minimum compliance thresholds and sector-specific guidelines. • Develop international guidance and tools to support standardized collection, metadata tagging and validation of citizen science data, enhancing quality, comparability and usability.
Ensuring transparency and provenance tracking	• Promote adoption of common provenance standards (e.g., PROV-aligned metadata, OPM) and their implementation in metadata markup (e.g., ISO 19115, schema.org, DCAT). • Automate provenance metadata capture through sensors, IoT devices and data management platforms. • Use digital signatures, DOIs, ORCID IDs and blockchain tools to certify dataset authenticity and trace lineage. • Ensure AI-generated data are transparent, with documented training sets, models and transformation methods. • Align environmental data policies with AI use, requiring structured metadata and traceability.
Preserving confidence and trust in environmental data	• Establish collaborative audit mechanisms and independent validation procedures for sensitive or prioritized datasets to strengthen transparency and confidence, while respecting national data ownership. • Build assurance systems for corporate environmental data, including third-party validation / verification and standardized reporting. • Certify repositories with trust standards like CoreTrustSeal and integrate user feedback mechanisms. • Recognize and incorporate measures to ensure CARE compliance for Indigenous data, with safeguards for community control and attribution. • Consult local communities to ensure their insights, needs and concerns are incorporated into quality assessments of data from their localities.

Aligning data generation with decision-making needs	• Define core and non-core environmental indicators that align with national policy priorities and global goals. • Establish shared data product specifications linking policy goals to data needs (e.g. flood risk maps) to guide relevant, efficient data generation. • Incentivize academic institutions to generate actionable, well-documented and open-access datasets. • Transform EO data into formats aligned with national administrative and policy needs (e.g., analysis ready data (ARD) frameworks). • Improve access to decision-relevant datasets for businesses (e.g., emissions factor databases, risk maps). • Promote granular, disaggregated corporate reporting through PRTRs, UNTP Digital Facility Record and UNEP FI tools.
Responding to the need for integrated data and assessments	• Strengthen cross-domain data integration through national coordination, interdisciplinary networks and platforms like the Livable Planet Observatory. • Link environmental data with health, food and socio-economic indicators to enable equity-focused policymaking. • Build the knowledge base for integrated assessments by strengthening data infrastructure, including an emphasis on complex human-environment systems and transformational change.

2.3 Pillar III: Interoperability

Scope and vision

The interoperability pillar addresses the measures needed to ensure the distributed components of the environmental data ecosystem work together (i.e. interoperate) with minimal overheads. At its core, interoperability is enabled by the combined use of common data formats, semantic standards and data models, which together define how environmental information is structured, related and exchanged across systems. Components should be able to discover, access, process, and understand one another's data without the need to perform conversions or transformations, often losing information and incurring significant costs (financial and environmental, due to increased energy use) in the process.

In the interoperability context, **achieving UNEP's vision would imply that, in 2035, data flowing through the global environmental data ecosystem are discoverable, accessible and (re)usable with minimal processing**. Diverse datasets can be integrated rapidly and at low-cost across platforms, domains and regions, fostering collaboration, innovation and informed decision-making. Using globally oriented, cross-domain interoperability standards, it also connects environmental data with social and economic information for holistic analysis.

Challenges

The vast potential of environmental data is constrained by a range of persistent and structural challenges. Scientific data on the same parameter are often collected using different methods, limiting comparability and complicating integration. This problem is compounded by a **lack of interoperable data formats, standards and semantics**, despite the existence of multiple international frameworks. Metadata standards are uneven, formats often require costly reprocessing and the semantics used to qualify data vary widely, undermining integration, discoverability and machine actionability. Data models, defining the structure and relationships of environmental information, are often inconsistent or absent, making it difficult to combine datasets or build scalable applications.

There is also a critical **lack of interoperability across (meta)data formats and semantics, as well as ecosystem-wide documentation and workflows**. Many projects produce outputs using idiosyncratic or highly domain-specific formats and semantic markup, and without publishing transparent workflows, version histories or access protocols. Weak documentation and the absence of semantically qualified links between datasets make it difficult to replicate methods or integrate information across domains, regions and institutions, limiting data reuse and scalability.

Data sharing is further constrained by the **underdevelopment and fragmentation of machine-to-machine infrastructure,** including Application Programming Interfaces (APIs) and data mediation endpoints. Many environmental platforms still rely on manual downloads over graphical user interfaces and lack machine-to-machine interfaces governed by consistent protocols. This prevents automation, creates inefficiencies and limits real-time data integration. Without widespread adoption of open, standardized machine-to-machine interfaces, environmental data remains siloed and difficult to access at scale.

Efforts to render data and digital systems interoperable are important to ensure efficient and low-cost environmental data exchange, integration and data-driven action. However, these measures must also support the flow of innovative or unexpected forms of data, containing these in stable, interoperable structures. There is therefore a need to **balance definitiveness and flexibility in interoperability specifications and frameworks**.

The **dominance of proprietary software and closed data ecosystems** can also pose a challenge. Cloud-based and commercial platforms may offer technical and cost advantages but may also negatively impact data-level interoperability by imposing local/vendor-specific standards, and limiting accessibility, transparency and long-term sustainability. Vendor lock-in, restrictive licensing and incompatible formats can isolate datasets and obstruct collaboration — particularly for organizations lacking the technical or human capacities to access such data.

Interoperability is also undermined by the **fragmentation of ESG and product-level environmental data**. Inconsistent disclosure frameworks, incompatible methodologies and misaligned indicators make it difficult to connect corporate data with public reporting systems. Without standard formats for product-level environmental information, such as carbon footprints or recyclability, sustainability claims remain hard to verify or scale.

Finally, **data ecosystems are often unable to keep pace with the growing use of AI technologies**, with potentially major implications for interoperability. Data formats, metadata, accessibility, licensing and semantic structures need to be reviewed to ensure that AI systems can interact with data in ethical, transparent and meaningful ways, including through the use of data in machine learning and knowledge graphs.

System-wide responses

Focus area	Key actions
Harmonizing data formats, standards and semantics	• Define requirements for (meta)data formats, semantics and other standards to be fit for purpose, and work with standards organizations to update or extend existing standards accordingly, avoiding unnecessary creation of new ones. • Promote the adoption of open standards (e.g. from ISO, OASIS, OGC, UN/CEFACT, W3C) to support long-term interoperability and transparency, and avoid lock-in to specific vendors or systems. • Use open, standards-based and cross-domain data formats like JSON-LD, GeoJSON, GeoTIFF/COG, Parquet and ODatato ensure integration across domains. • Implement widely understood metadata standards (e.g. ISO 19115, schema.org, DCAT) to improve data discoverability and reuse, and connect these to policy-oriented standards (e.g. SDMX). • Support semantic clarity and interoperability by implementing high quality domain-specific and cross-domain semantic resources (e.g. vocabularies, ontologies), such as AGROVOC, Darwin Core, Environment Ontology, GEMET, the GCMD (Global Change Master Directory) and LEO (Law and Environment Ontology). • Engage the operators of key semantic resources and create officially recognized and reliable maps between them to support high-quality conversions/mediation and data commons platforms. • Promote the use of linked (open) data formats (e.g. RDF, OWL) to enhance transparency, observability and machine-actionability, and promote cross-domain integration through alignment with semantic web practices. • Promote the development and adoption of standard data models (e.g. ISO 19109, OGC Features and Geometries) to structure environmental data consistently across systems and domains.
Promoting workflow and documentation interoperability	• Require documentation of complete data workflows (inputs, tools, processing, outputs) to support reproducibility, provenance tracking, trust and reuse. • Promote open workflow platforms and standards (e.g. git-based development workflows, WorkflowHub, CWL, WDL) for transparency and collaboration. • Adopt version control practices and granular use of persistent identifiers (e.g. W3IDs and DOIs) to track dataset updates and changes.
Enhancing machine-to-machine infrastructure	• Expand the use of machine-to-machine interfaces (e.g. APIs, MQTT servers) across environmental platforms and fund upgrades for legacy systems. • Align machine-to-machine interface design with open standards (e.g. openEO, OpenAPI, OData) and ensure data are machine-readable and machine-actionable.

	• Support data mediation systems to serve data in the open formats and semantic markup needed by consumer systems, leveraging the semantic maps noted above. • Establish centralized indexing of environmental APIs and other machine-to-machine services / interfaces to improve discoverability and access, as done, for example, by the ODIS Catalogue of Sources (ODISCat). • Create monitoring solutions across the ecosystem to cross-verify that APIs are live and delivering high-quality, interoperable (meta)data. • Integrate regular use of machine-to-machine interfaces into national monitoring systems and private-sector tools to enable real-time, policy-relevant data use.
Balancing harmonization and flexibility in interoperability protocols	• Foster convergence around shared formats and protocols (e.g. STAC, Schema.org, DCAT), supported by stakeholder dialogue. • Support modular, phased implementation of standards to reduce complexity for low-capacity users and facilitate incremental adoption. • Encourage federated data architectures where local actors maintain control but align with shared semantics and standards. • Leverage existing institutions (e.g. ISO, OASIS, OGC, UN/CEFACT) and donor influence (e.g. funding conditions) to promote adoption. • Regularly monitor progress and identify remaining interoperability gaps across regions and domains.
Navigating proprietary software and closed data ecosystems	• Invest in open-source alternatives to mitigate vendor lock-in and ensure long-term access (e.g. QGIS, Open Data Cube), ensuring support for import/export of (meta)data using open, well formed and widely adopted standards. • Support national and global open-source repositories and code-sharing platforms (e.g. Zenodo, Open CoDE). • Adopt open, non-proprietary and globally oriented Analysis-ready, Cloud-optimized (ARCO) formats and standards (e.g. Apache Parquet, Zarr). • Promote cross-platform interoperability through open formats, common API frameworks and well-coordinated data mediation services. • Engage cloud providers to negotiate licensing and accessing conditions for public environmental data that is repackaged or monetized through proprietary applications and platforms (e.g. commercial weather or mapping services).
Improving interoperability in corporate ESG and product-level disclosures	• Support international coordination to align ESG reporting frameworks on key metrics (e.g. Scope 3, nature-related risks). • Harmonize corporate and public data systems through shared taxonomies, metadata protocols and data mediation services, including both structural and semantic conversion tools. • Develop minimum standards for product-level data and Digital Product Information Systems (e.g. lifecycle methods, open vocabularies).

	• Use initiatives like the UN Transparency Protocol and UNEP Life Cycle Initiative to guide alignment and data baselines. • Promote convergence of corporate sustainability disclosures with MEA, SDG and national reporting systems. • Use digital permanent identifiers to track products and associate them with other data linked with them.
Leveraging AI to improve interoperability	• Ensure digital strategies include components to increase awareness and literacy regarding the effective and ethical use of AI solutions. • Ensure that (meta)data conventions and standards support both machine learning (ML) and knowledge representation (KR) approaches in AI, using generic and open conventions that do not favour specific tools or providers. • Invest in training and capacity-building in AI skills, integrating them into digital literacy programmes, especially in under-resourced contexts. • Develop open-source AI tools designed to consume and produce data released in open, domain-neutral formats and semantic standards, and allocate long-term funding for scalable integration of AI into environmental workflows. • Create and sustain processes to continuously cross-validate, verify and audit AI solutions to ensure accuracy and robustness, assessing the transparency of any AI solution deployed. • Establish and maintain authoritative, sustainable ontologies and taxonomies to provide semantic structure for AI, and compatibility with knowledge graph technologies. • Develop and/or apply suitable ethical, legal and governance frameworks for AI-generated metadata (aligned with sound implementation of the FAIR, CARE and TRUST principles). • Create shared toolkits, clear guidelines and standard operating procedures to guide AI adoption, including readiness assessments and case studies.

2.4 Pillar IV: Accessibility and affordability

Scope and vision

This pillar addresses measures to ensure that all stakeholders can access and afford the environmental data needed to support sustainable development. Issues relating to infrastructure and connectivity, which are essential for data access and affordability, are taken up under Pillar V on capacity-building.

In the accessibility and affordability context, **achieving UNEP's vision would imply that, in 2035, the global environmental data ecosystem ensures equitable, sustainable and secure access to high-quality data and tools, while ensuring robust protections for data sovereignty and privacy**. It is supported by affordable pricing structures, user-friendly platforms and strong collaboration across sectors. It prioritizes transparent licensing, ethical governance and rapid data sharing in emergencies, creating resilient infrastructures that empower stakeholders to use environmental data effectively for decision-making.

Challenges

Many valuable environmental datasets remain underutilized because **repositories are difficult to find and access**. Researchers, policymakers and civil society actors often struggle to locate existing datasets, which are dispersed across institutions, platforms and regions. In many cases, data are stored in non-machine-readable formats, local archives or PDF reports that hinder reuse. Without consistent cataloguing, discoverability remains limited, especially in low-capacity environments. Fragmentation across initiatives and underinvestment in repository maintenance further obstruct long-term accessibility and integration.

Access to critical datasets is also restricted because **the costs of data acquisition, storage and management remain high**, particularly for low-income countries and under-resourced institutions. Proprietary datasets such as high-resolution satellite imagery or ESG databases are often priced beyond the reach of researchers and public agencies. Maintaining open platforms and managing real-time or large-scale spatial data requires substantial financial and technical resources. The absence of fair, replicable cost-sharing models undermines the sustainability of open access and limits the public value generated from environmental data.

Even where datasets exist, **access is constrained by concerns about sensitive and strategic information**. Governments and institutions may restrict data on national security, critical infrastructure, Indigenous lands or protected species to prevent misuse. But institutional fears over misinterpretation, legal exposure or reputational harm also contribute to excessive caution. As a result, raw data are often withheld or released only in static formats, while legal and bureaucratic barriers delay or complicate access even for non-sensitive datasets.

Growing reliance on private infrastructure and data holdings means that **commercial interests increasingly shape who can access environmental data**. Key datasets are controlled by private firms in sectors such as finance, transport and energy, with limited sharing due to intellectual property concerns, competitive secrecy and weak incentives. Cloud-based systems offer scalability but increase dependence on a small number of providers, raising risks related to affordability, vendor lock-in and long-term data sovereignty, especially for countries with limited negotiating power.

Finally, the impact of environmental data is diminished because **many platforms are not designed with users in mind**. Interfaces are often unintuitive, with limited tools for exploration, analysis or decision support. Non-experts, local authorities and marginalized groups are frequently excluded from meaningful data use. Without feedback loops, user-centred design or sustained platform maintenance, usability declines over time. The proliferation of fragmented, short-lived platforms further reduces coherence, interoperability and trust in the digital environmental ecosystem.

System-wide responses

Focus area	Key actions
Ensuring that repositories are findable and accessible	• Strengthen data discovery and cataloging systems through open repositories (e.g. ODIS, OpenAIRE) and harmonized metadata standards (e.g. DCAT, STAC). • Improve accessibility of repositories by digitizing legacy data and ensuring non-proprietary, machine-readable formats (e.g. CSV, NetCDF). • Promote open, machine-readable ESG reporting formats and public data portals using open APIs and structured formats (e.g. XML, JSON, RDF). • Develop regional data repositories with long-term funding and coordination, ensuring that publicly funded data are stored in accessible formats. • Develop long-term preservation strategies for environmental data using federated storage models, integrity checks (e.g. blockchain) and sustainable funding.
Reducing cost barriers to data access	• Expand open access to publicly funded data by mandating open release policies and implementing global open data standards (see e.g. the UNESCO Open Science Recommendation). • Create incentives for data sharing through financial and technical support for countries adopting open data frameworks. • Develop open data platforms based on open standards and federated architectures (e.g. GBIF, Copernicus, World Bank Open Data). • Increase investment in national and regional infrastructure to reduce private cloud dependency and support affordable data storage and processing. • Create sustainable business models (e.g. tiered access, public-private partnerships, revenue sharing) to finance open data provision.
Balancing access against concerns about strategic and sensitive data	• Facilitate uptake of open data licences (e.g. Creative Commons) with decision-support tools to guide licensing choices. • Reduce bureaucratic barriers through digitized approvals, API-based authentication and compliance with transparency rules (e.g. Aarhus Convention). • Create classification frameworks and tiered access models to differentiate between open and restricted data and manage them responsibly. • Negotiate protocols to international agreements to align rules for sensitive data access (e.g. building on Nagoya Protocol or Aarhus frameworks). • Apply technical safeguards such as federated data sharing, distributed ledgers and privacy-preserving AI to enable secure use of sensitive data. • Reference frameworks such as the EU Data Governance Act, which offer mechanisms for data intermediation and data altruism, and promote responsible data sharing across public and private actors.

Navigating commercial interests and cloud dependency	• Incentivize broader access to private-sector environmental data through legal disclosure requirements, voluntary schemes and clearer materiality definitions. • Embed safeguards for secure private-sector data sharing through privacy-preserving architectures, encryption and trust frameworks (e.g. Gaia-X). • Support innovative sharing frameworks like data trusts and data spaces that align commercial and public interests. • Establish selective redaction standards to protect sensitive supply chain data while enabling traceability and downstream transparency. • Develop licensing frameworks that clarify reuse and monetization rights while ensuring open access to publicly funded datasets. • Reduce dependency on single cloud providers by encouraging competition, ensuring redundancy and safeguarding equitable access.
Creating user-oriented data platforms	• Prioritize user-centered design by aligning platforms with real-world decision needs and building intuitive, action-focused tools (e.g. FAO EarthMap). • Use AI to enhance accessibility through tools like GeoGPT that support plain-language queries, metadata generation and decision support. • Engage with users via real-time feedback, participatory design and community forums to ensure continuing platform relevance. • Reduce platform duplication by promoting federated data ecosystems and modular, interoperable systems that connect complementary tools. • Ensure long-term maintenance through sustained funding, open-source development models and partnerships that preserve accessibility and adaptability.

2.5 Pillar V: Capacity-building

Scope and vision

The capacity building pillar includes measures to develop the broad range of capacities needed for effective environmental data governance: data collection, processing, sharing, communication and use in policymaking processes. This ranges from physical infrastructures and tools, through skills, knowledge and institutions, to financial resources.

In the capacity-building context, **achieving GEDS vision would imply that, in 2035, all stakeholders within the global environmental data ecosystem are empowered with the skills, knowledge, infrastructures and tools needed to gather, analyse and use environmental data effectively**. It ensures affordable and reliable storage solutions and secures sustainable financial support for long-term impact. This system bridges the gap between data, policymaking and decisions, transforming environmental data into a powerful tool for global collaboration and sustainable development.

Challenges

Environmental data ecosystems are characterized by capacity limitations, especially in low- and middle-income countries. The **absence of foundational information and communication technology (ICT) infrastructure**, including in-situ monitoring hardware, broadband connectivity and scalable data systems, undermines the collection, transmission and processing of accurate environmental data. Many agencies lack access to cloud computing and modern storage systems, leaving datasets fragmented, outdated and difficult to use.

Even where data are collected, **limited access to data management and processing resources** impedes its effective use. Scalable storage options like data lakes are underutilized and cloud-based analytical platforms remain out of reach due to cost, technical complexity or policy constraints. Advanced tools such as AI, machine learning and blockchain are rarely deployed at scale, while duplicative tool development across institutions wastes resources and reinforces fragmentation.

Underlying these technical gaps are **pervasive deficits in skills and knowledge** across the entire data lifecycle. Many countries lack expertise in designing monitoring frameworks, calibrating sensors, processing data or using it to inform policy. Skills in areas like data validation, geospatial analysis, statistical modeling and visualization remain scarce. Training is often donor-driven, one-off and focused on central institutions, leaving the local governments and communities that are key actors in environmental monitoring without adequate support or resources.

Efforts to **strengthen institutional capacities face systemic constraints**. Environmental agencies struggle to recruit and retain qualified professionals, who are often drawn to better-paid private or international roles. High staff turnover disrupts data continuity and limited professional development pathways inhibit long-term expertise retention. Public institutions frequently operate without formal mechanisms to engage corporate actors or align reporting standards, resulting in fragmented environmental data ecosystems. Weak governance frameworks often prevent data from informing real-time decisions, such as disaster response, while institutional silos limit collaboration between scientists, statisticians and policymakers.

Compounding all these challenges is a **chronic lack of sustainable funding for data governance**. Many governments depend on short-term, project-based financing, which leaves systems fragile and datasets incomplete or inaccessible over time. Without dedicated investment in infrastructure, skills and institutional frameworks, environmental data systems will remain underpowered and unable to support urgent climate and sustainability goals.

System-wide responses

Focus area	Key actions
Developing foundational ICT infrastructure	• Invest in modern, cost-effective environmental monitoring equipment, including IoT-enabled sensors and remote sensing tools. • Expand broadband, mobile and satellite connectivity in underserved regions, prioritizing remote monitoring areas.

	• Support the deployment of edge computing to reduce reliance on high-speed centralized infrastructure. • Build interoperable national and regional data hubs for storing and processing large-scale datasets. • Map infrastructure gaps to identify investment priorities and coordinate multi-stakeholder solutions.
Ensuring access to data management and processing resources	• Facilitate institutional access to cloud and hybrid storage systems through public subsidies and policy incentives. • Promote open-source, low-cost data management frameworks to reduce vendor lock-in. • Enable adoption of high-performance cloud platforms by negotiating non-commercial access for public institutions. • Promote coordination in tool development through international working groups and shared standards. • Fund modular, interoperable tools optimized for low-bandwidth environments and regional contexts. • Create shared repositories and transparency standards for open-source analytical tools.
Building needed skills and knowledge	• Embed environmental data training in university programs and technical institutes, with scholarships for underrepresented regions. • Create multilingual, open-access digital learning platforms covering the full data pipeline. • Develop agile, modular training programs to adapt to fast-evolving technologies. • Establish regional knowledge hubs to provide tailored technical assistance and peer-to-peer learning. • Partner with tech firms to offer fellowships and mentorships in cloud computing, AI and geospatial analysis. • Support AI literacy and ethics training for policymakers and regulators. • Develop public-private training programs to build ESG and sustainability reporting capacities across sectors.
Strengthening institutional capacities	• Create dedicated interdepartmental units to coordinate environmental data across government. • Professionalize data management: establish clear career pathways, salary incentives and training for data specialists in public institutions. • Combine open government commitments with integrated data platforms for evidence-based policy. • Design real-time dashboards and tools that link environmental data with planning and governance functions.

	• Formalize public–private coordination through advisory panels and working groups to align regulatory frameworks and reporting standards.
Securing sustainable funding for data governance	• Mainstream environmental data governance in national development budgets and legislative mandates. • Leverage global climate and development finance (e.g. Global Environment Facility, Green Climate Fund) for long-term environmental monitoring investments. • Explore new funding mechanisms including data subscriptions, green bonds and environmental data services. • Establish multi-year funding streams for data maintenance, storage and institutional continuity. • Engage philanthropic and private sector partners to co-finance infrastructure and capacity development, particularly in low-income countries.

3 Strategic intervention points for transforming the environmental data ecosystem

Chapter 1 sets out the GEDS vision that, by 2035, we have:

> *A trusted, inclusive, accessible and interoperable environmental data ecosystem that enables collective action at the speed and scale needed to solve the triple planetary crisis and support sustainable economies and societies worldwide.*

Chapter 2 outlines diverse problems and shortcomings in the global environmental data ecosystem, ranging from weak institutional mandates and infrastructures to limited interoperability and insufficient access to data, especially in low- and middle-income countries. Yet it also highlights diverse opportunities for actions at international, national and subnational scales that could drive forward transformational change. Across sectors and regions, innovative practices that are already emerging that point the way forwards.

Drawing on the wide array of possible responses outlined in Chapter 2, this chapter identifies eight strategic intervention points where concerted actions by stakeholders could unlock significant progress toward the 2035 vision (Figure 3.1). These intervention points are also areas where UNEP is well placed to contribute, given its global mandate and convening role, and its strength in developing frameworks and tools that enable action by others.

Each section (3.1–3.8) explains:

- why the intervention point is a priority, based on the needs and gaps identified in Chapter 2;
- what success could look like if the GEDS vision were implemented in the next decade;
- what is needed from different actors, including governments, regional organizations and development partners, the private sector and civil society;
- where UNEP could contribute to enabling progress, in coordination with other stakeholders.

The UNEP actions are not prescriptive but are intended to inform dialogue with Member States and guide resource mobilization efforts. Since many of UNEP's proposed contributions involve the creation of tools, frameworks and platforms to be implemented by others, their impact will depend on active piloting and uptake by Member States and other partners.

To support this, Annex I on "Proposed approach for UNEP actions under GEDS" outlines the activities and costs associated with each of enabling actions, distinguishing between UNEP's contributions and broader implementation measures led by other stakeholders. It also presents proposals for a stakeholder-led implementation model and pooled funding mechanism, capable of coordinating and resourcing delivery in an agile and adaptive way.

Figure 3.1 Targeted intervention points to address systemic challenges and realize the GEDS vision

Pillar	Challenge	Intervention point	Vision by 2035
Governance	Weak and fragmented governance leads to inconsistent practices and insufficient safeguards for ethical and sustainable data use.	1. Developing national environmental data strategies and policies.	Global environmental data governance is coordinated and transparent, ensuring data sovereignty while enabling effective collaboration.
Quality and provenance	Environmental data often lacks consistency, documentation, and traceability, undermining its reliability for decision-making.	2. Strengthening environmental data quality and trust frameworks. 3. Aligning around essential variables and shared scientific standards.	Environmental data are accurate, consistent and fit for purpose, supported by robust processes and validation, and complete metadata.
Interoperability	Fragmented systems and incompatible standards hinder the integration and comparison of environmental datasets.	4. Harmonizing interoperability standards for environmental data. 5. Ensuring consistent and credible product sustainability disclosures.	Environmental data are discoverable, accessible and reusable with minimal processing, and can be rapidly integrated at low cost to drive innovation and action.
Accessibility and affordability	High costs and access barriers limit the use of critical environmental data, reinforcing global data inequalities.	6. Delivering federated access to environmental data. 7. Promoting equitable access to essential environmental data.	Access to high-quality data and tools is equitable, sustainable and secure, with strong safeguards for sovereignty and privacy.
Capacity-building	Many countries and organizations lack the skills, tools, and infrastructure to manage and use environmental data effectively.	8. Building needed capacities – human, institutional and technical.	All stakeholders have the skills, infrastructure and tools needed to collect, analyse and use environmental data effectively.

3.1 Intervention point 1: Developing national environmental data strategies and policies

Why this is a priority

Strong institutional frameworks are the backbone of effective environmental data governance. Without coordinated mandates, clear legal frameworks and sufficient capacities, environmental data remains fragmented, underutilized and poorly maintained. Many countries struggle with institutional silos, unclear responsibilities, skills shortages and outdated data-sharing practices. National environmental data strategies provide a foundation for overcoming these challenges by establishing clear roles, fostering inter-agency coordination, embedding global best practices and ensuring alignment with digital transformation and open data agendas.

UNEP and other international partners can play a valuable role in supporting governments to develop and implement national environmental data strategies. Foundations already exist in several domains. For example, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) Integrated Geospatial Information Framework (IGIF) provides a widely used roadmap for national geospatial development. Building on such frameworks can help ensure technical coherence, institutional legitimacy and alignment with broader digital governance agendas.

What success would look like

By 2035, all countries have made substantial progress toward establishing national frameworks for environmental data governance. For example:

- A growing number of countries across all regions have adopted national environmental data strategies that define clear institutional roles, legal mandates and coordination mechanisms (or integrated these elements into broader national data strategies).
- Environmental data governance principles such as FAIR, TRUST, CARE and openness are embedded in national digital and environmental policies, with countries adapting these to local legal, institutional and technological realities.
- Governments are applying consistent data management practices, such as requiring data management plans for large public projects and using common metadata standards.
- Governments have aligned their environmental data strategies with national geospatial development plans, building on frameworks like the UN-GGIM IGIF.
- Regional and South-South cooperation has expanded, helping to build shared approaches, training programmes and peer-to-peer technical assistance
- Governments have established open, machine-readable platforms to support decision-making and public accountability and institutionalized dedicated units to coordinate actions across departments and agencies.
- National strategies recognize the value of diverse data sources, including citizen science, and define appropriate mechanisms to integrate them into monitoring and statistical systems.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Develop and implement national strategies; create legal mandates; establish coordinating bodies and staffing pipelines.
Regional organizations	Embed core data governance principles (FAIR, TRUST, CARE) in regional guidance and support country uptake.
Development partners and philanthropic actors	Fund capacity-building, institutional strengthening and career development pathways.
Academia and private sector	Contribute to development of knowledge, skills, tools and data infrastructures.

UNEP's contribution

Member States could mandate UNEP to **develop a "Guidance Framework for Environmental Data Governance"** to support countries in creating and strengthening national environmental data strategies and policies by 2035. The framework would be co-developed with Member States, regional organizations and relevant partner to ensure that it reflects the needs and capacities of diverse contexts.

UNEP's role would focus the design and delivery of this global framework, which would:

- set out core governance principles, including sovereignty, privacy, ethics, security and internationally recognized standards such as FAIR, TRUST, CARE and openness;
- outline options and examples for integrating diverse data sources, including citizen science, into national data strategies;
- provide adaptable templates and tools for strategy development, data classification, inter-agency coordination and metadata and interoperability standards;
- serve as a baseline of best practices that UNEP can help tailor to specific national and regional contexts;
- address the environmental data needs of the private sector by identifying shared public–private data priorities, promoting open access to foundational datasets and encouraging business participation in national data governance processes;
- support progressive realization across countries at different levels of institutional capacity, with differentiated pathways and implementation support mechanisms.

UNEP would not be responsible for implementing national strategies, other than engaging with selected pilot countries during the framework's design phase to test approaches, collect feedback and refine the framework. Broader uptake and implementation would be led by governments and other partners, such as regional organizations or development agencies. Such partners would be responsible for delivering technical assistance, adapting tools to national contexts and supporting institutional integration.

3.2 Intervention point 2: Strengthening environmental data quality and trust frameworks

Why this is a priority

Confidence in environmental data is essential for effective decision-making, accountability and public trust. In practice, however, this confidence is often undermined by inconsistent methods, missing metadata, unverifiable sources and questions around fitness for purpose. In a world increasingly reliant on AI-generated products, satellite-derived indicators and corporate sustainability data, users must be able to evaluate the reliability and appropriateness of the datasets they rely on for each specific use case.

Some global environmental datasets are already generated through established international science-policy processes with robust quality assurance protocols, such as MEA scientific bodies, the IPCC and IPBES. However, these authoritative sources represent only part of a much broader and increasingly diverse data landscape. A global effort is needed to embed systematic quality assurance and trust mechanisms across the environmental data ecosystem. This means implementing routine data profiling and audit processes, developing tools for bias detection and uncertainty analysis, and creating minimum quality thresholds and sector-specific standards. It also requires better mechanisms for provenance tracking, such as digital signatures and structured metadata, and wider adoption of trust frameworks like FAIR, ISO 8000 and CoreTrustSeal certification.

Efforts to improve data quality are needed across domains and data pipelines – from calibrating low-cost air quality sensors, to harmonizing ESG and product-level reporting, to developing model-based gap-filling methods where national data are missing. Provenance, validation and appropriate use must be built into both data governance systems and user-facing platforms, including AI applications.

What success would look like

By 2035, a robust system of environmental data quality assurance and trust frameworks is in place globally, enabling users to verify, interpret and responsibly apply environmental data. For example:

- Governments and institutions routinely apply national quality assurance/quality control (QA/QC) protocols aligned with global standards, including calibration, triangulation and fusion of Earth observation, in situ and citizen-generated data.
- Internationally agreed data quality levels and provenance standards are widely adopted, helping users assess source credibility, uncertainty and appropriate use.
- Modelled and AI-generated datasets meet transparency and validation requirements, with clear metadata documentation of training data, assumptions and transformation methods.
- Corporate environmental disclosures are standardized and subject to third-party audit, with open access to metadata and quality indicators.
- Relevant environmental data repositories are certified against recognized data stewardship and repository standards (e.g. CoreTrustSeal, FAIR) and include user feedback mechanisms to support continuous improvement.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Establish and enforce national QA/QC protocols; mandate provenance standards and metadata requirements for public datasets; invest in validation infrastructure and sensor calibration facilities.
Research institutions and standards development organizations	Support development and alignment of international QA/QC, provenance and transparency standards (e.g. ISO, FAIR); facilitate regional coordination on validation protocols and cross-border data comparability.
Scientific and technical bodies	Advance methods for bias detection, triangulation and model validation; contribute to development and testing of sensor calibration protocols; co-develop data quality indicators and audit tools.
Civil society and community-based networks	Develop and scale best-practice citizen science and other community-based environmental data initiatives to inform regional and global environmental monitoring programmes.
Data platforms and repositories	Where appropriate, apply certification frameworks (e.g. CoreTrustSeal); embed quality indicators and provenance metadata in public interfaces; support user feedback and multi-actor validation processes.
Private sector	Adopt standardized data quality and provenance practices in ESG and product-level reporting; support third-party validation of disclosures; contribute to open calibration datasets and peer-reviewed tools.

UNEP's contribution

Member States could mandate UNEP to **establish a global mechanism for environmental data quality assurance**, designed as a pragmatic, voluntary service to build trust in environmental data and promote best practices in data collection, processing and use. Data providers could voluntarily submit their datasets for assessment, receiving a UNEP-backed quality label that signals credibility. Operational delivery of the voluntary assessment service, as well as technical assistance to data providers, would be led by Member States and implementation partners.

The mechanism would adopt an incremental approach, offering structured but lightweight support to governments, researchers and businesses seeking to assess or demonstrate the reliability of their datasets. The initiative would draw on and complement existing standards, such as the FAIR and TRUST principles, ISO 8000 quality standards and repository certifications like CoreTrustSeal, focusing specifically on the environmental domain and applying these principles to assess specific datasets.

As part of this function, UNEP could convene expert groups to co-develop a flexible classification system that defines levels of data quality and recommended application contexts, for example whether a dataset is suitable for policy enforcement, long-term trend analysis or exploratory research. This system could incorporate indicators for fitness-for-purpose and certainty levels, helping users interpret and compare datasets with greater confidence.

To support data providers, a scoring system (e.g. 1 to 5 stars) could also be used to help data providers identify what specific improvements are needed to enhance trust, usability and policy relevance. The design of the system could draw on elements of the EU's Open Data Maturity Framework (EU, 2025).

To ensure broad relevance and uptake, UNEP would co-design the mechanism through inclusive consultation during the initial scoping phase, engaging a wide range of stakeholders across sectors and regions. Early adopter organizations could then help pilot and refine the approach during rollout. By emphasizing simplicity and clarity, and involving stakeholders from the outset, the mechanism would help embed quality assurance more deeply across the data ecosystem without imposing rigid mandates.

3.3 Intervention point 3: Aligning around essential variables and shared scientific standards

Why this is a priority

Pillars I–IV each point to the value of identifying priority environmental variables as a strategic foundation for more effective and equitable data systems. Establishing essential variables helps to manage data overload, allowing countries and institutions to focus efforts and investments on the most policy-relevant measurements. It supports coherence and harmonization across fragmented reporting systems, based on standardized scientific protocols for data collection, quality assurance and assessment. Essential variables also facilitate interoperability and open access, serving as the common language that links different platforms, domains and actors across the global environmental data ecosystem.

These advantages underpin the growing momentum to define core or essential variable frameworks in various domains. Much important work has already been done through initiatives such as the Essential Biodiversity Variables (EBVs), Essential Climate Variables (ECVs) and Essential Ocean Variables (EOVs) demonstrate how scientifically grounded variable sets can align observation systems and policy processes. However, uptake remains uneven across domains. Some areas, notably pollution, chemicals, noise and land degradation, lack comprehensive or widely adopted frameworks. Other domains, such as policy tracking, lack equivalent variable structures, despite their critical importance for assessing governance responses. The task now is to build on these efforts and reach broader international consensus, ensuring coherence across domains and widespread adoption.

Similarly, while there is some progress in identifying core environmental indicators, for example through the SDGs or UNECE's priority indicators for the pan-European region, coverage remains patchy. Countries also face pressure to report across multiple, overlapping environmental agreements. Greater consolidation and alignment of indicators, for example across the Rio Conventions (the United Nations conventions on biological diversity, climate change and desertification) would ease reporting burdens, improve efficiency, and enable more coherent and synergistic tracking of global commitments.

What success would look like

By 2035, a trusted, inclusive, accessible and interoperable environmental data ecosystem enables collective action at the speed and scale needed to solve the triple planetary crisis and support sustainable economies and societies worldwide.

- A coherent set of essential environmental variables and core indicators is established across major domains, building on existing frameworks under MEAs and other UN entities (e.g. climate and biodiversity), and addressing gaps in areas such as pollution. Such variables form the foundation for consistent data collection, integrated assessments and global stocktaking.
- Robust, standardized scientific protocols for data collection, processing and validation of the essential environmental variables are widely adopted, ensuring data quality, comparability, MEA alignment and policy relevance across regions and sectors.
- Countries and stakeholders have clear investment pathways and institutional guidance to build the infrastructure, skills and systems needed to generate and apply essential environmental variables over time.
- A harmonized global framework for policy tracking is in place, enabling consistent, transparent and sustained assessment of environmental laws, institutions and governance actions across countries and domains.
- Data systems for generating essential environmental variables are aligned across domains and scales, enabling coherence in global monitoring, reducing needless duplication of effort and supporting integrated progress tracking for global targets and commitments.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Integrate essential variables into national monitoring and reporting systems; prioritize investment in data collection aligned with standardized protocols; coordinate across ministries to ensure coherence; adopt the principle of "collect once and report many times"; support uptake of harmonized policy tracking indicators.
International and regional organizations	Facilitate alignment of essential variable frameworks across domains and MEAs; promote adoption of open, standardized scientific protocols; support gap-filling in underrepresented areas (e.g. chemicals, governance); provide guidance on harmonized policy indicator development.
Scientific and technical bodies	Co-develop and refine essential variable definitions and protocols; develop tools for uncertainty estimation, harmonization and validation.

Private sector	Contribute relevant data aligned with essential variable frameworks; adopt shared indicators and reporting protocols in ESG frameworks; support innovation in policy tracking and cross-sector integration.
Civil society, Indigenous groups, local communities	Participate in defining context-relevant variables and indicators; contribute community-based monitoring data where appropriate; use data for advocacy and accountability.

UNEP's contribution

Member States could mandate UNEP to lead a global coordination initiative to strengthen the coherence, coverage and **practical uptake of essential variables and indicators across environmental domains, anchored in rigorous "gold standard" methods for scientific data collection and assessment**. Rather than creating new variable frameworks, UNEP would work with partners to map, connect and support the adoption of existing efforts, while identifying gaps and enabling targeted improvements in underrepresented areas. Piloting of these protocols, delivery of technical training and integration into national systems would be led by Member States and development partners, using UNEP-developed resources as inputs.

This process would begin with a comprehensive mapping of existing essential variable and indicator frameworks, such as the EBVs, ECVs, EOVs and relevant MEA indicators, including associated protocols and quality standards. UNEP would produce a synthesis overview to help countries and stakeholders navigate these efforts, understand how they align and identify practical entry points for implementation.

Where gaps or fragmentation exist, such as in areas like waste, land degradation or environmental governance, UNEP would convene expert groups – in consultation with MEA secretariats – to support the identification and definition of essential variables, as well as the co-development of model protocols, building where possible on existing scientific standards. In parallel, UNEP would promote adoption through toolkits, training and coordination with stakeholders already active in global monitoring and assessment. The focus would be on enabling coherent, policy-relevant and interoperable environmental monitoring systems, with UNEP acting as a steward and convener, fostering alignment across initiatives and helping translate variable frameworks into actionable data strategies.

UNEP could also work with the secretariats of the Rio Conventions to identify opportunities for streamlining and aligning core indicators across MEAs. This would reduce reporting burdens on countries, enhance coherence in tracking environmental commitments, and support integrated implementation of global frameworks.

3.4 Intervention point 4: Harmonizing interoperability standards for environmental data

Why this is a priority

The lack of globally interoperable (meta)data formats, machine-to-machine interfaces and coordinated use of compatible semantic resources constitute a major barrier to environmental data sharing, discovery, access, integration and (re)use. Poor global interoperability is hampering the use of environmental data in global assessments, national policy design and cross-sectoral analysis. While numerous standardization initiatives exist, fragmentation persists due to overlapping mandates, insufficient coordination and varying capacities across countries and sectors.

Achieving true interoperability requires shared technical standards and practical implementation guidance, especially for environmental data platforms serving diverse stakeholders. Open-source communities have successfully built interoperable ecosystems at scale and offer valuable models for designing frameworks that are technically sound, widely adopted and sustainable over time. The SpatioTemporal Asset Catalog (STAC), for example, demonstrates how community-driven development, strong industry uptake and open governance can accelerate the creation and adoption of shared data protocols.

What success would look like

By 2035, environmental data systems across domains and regions have become significantly more interoperable and routinely share (meta)data with ecosystem partners, enabling effective data integration, improved usability and seamless access and use by a wide range of stakeholders, not only those working directly in the environmental domain. For example:

- Core environmental data domains – including biodiversity, land use, pollution (air, water, noise, soil) and climate – employ and verify / validate their (meta)data against global and cross-domain standards.
- Organizations establish, maintain and staff a persistent "interoperability layer" in their data systems, supporting the conversion of their local standards to ecosystem-wide standards.
- Major global and national data platforms use interoperable machine-to-machine interfaces (e.g. APIs), enabling on-demand integration, reuse and cross-platform searchability.
- Governments and organizations qualify and mark up their environmental datasets using high-quality, well-managed and verifiably interoperable and standards-compliant (e.g. W3C SKOS or OWL) semantic resources, supporting cross-sectoral and cross-border intelligibility.
- Globally recognized interoperability guidance and tooling, including semantic mapping services, metadata converters and open workflow standards, are widely available and used by data providers and platform developers, with training and capacity-building support in place to ensure individuals can effectively implement and maintain these approaches.
- Interoperability principles are embedded in the design of new data platforms using an "interoperability first" model, Earth observation infrastructures and sustainability disclosure systems, supported by persistent identifiers, linked (open) data standards and reproducible data workflows.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Adopt and implement interoperable data standards across national monitoring systems; upgrade legacy platforms to support open APIs and other machine-to-machine systems, supporting machine-readable and machine-actionable formats; participate in international standard-setting processes; create national hubs that can mediate national data to international systems efficiently and effectively.
International organizations and development partners	Promote harmonization of environmental data standards; provide technical assistance, training and tools for implementation; support alignment with cross-border and global frameworks; create regional hubs to mediate data to global stakeholders effectively.
Standards development organizations	Contribute technical expertise to environmental data domains; develop inventories of environmental data standards, building on recent ISO work (ISO, 2025); support extension and alignment of standards for specific use cases; work with other standards organizations to release official interconversion resources (including open-source software packages) between competing or redundant standards.
Technical agencies and academia	Contribute expertise on data modeling, API design, semantic integration and metadata standardization; support tool development and piloting; partner with national, regional or thematic data hubs to mediate interoperable data exchange with global partners.
Private sector and platform developers	Implement processes and data mediation components in organizational data systems to ensure APIs, metadata catalogues, data products and other digital assets interoperate with ecosystem partners; align corporate systems with public/open data standards; adopt new business models that support cross-platform interoperability; provide feedback to improve usability; share metadata on priced data products to enable transparent, cross-sector alignment between data needs and supply.

UNEP's contribution

Member States could mandate UNEP to **convene an Expert Group on Environmental Data Interoperability to coordinate and provide consistent guidance on the implementation of sustainable interoperability data architectures across the environmental data ecosystem**. This would include identifying viable data formats, metadata structures, semantic resources and machine-to-machine exchange across environmental domains. The focus would not be on developing new standards but rather agreeing to prioritize a selection across all domains, noting where extensions are needed.

UNEP would be responsible for convening the expert group, coordinating consultations and co-developing guidance and technical documentation. Governments, regional platforms, technical institutions and other partners would lead the development and piloting of reference implementations, contribute to training and outreach, and support dissemination and uptake. The work would follow a streamlined, collaborative model, emphasizing virtual engagement, open-source solutions and targeted technical contributions from partners to ensure broad participation and cost-effective delivery.

The Expert Group would engage with and build on existing initiatives led by, for example, the Committee on Data of the International Science Council (CODATA), the Group on Earth Observations (GEO), GBIF, OBIS, UNESCO-IOC and the World Meteorological Organization (WMO). Actions to construct inventories of relevant standards could provide valuable inputs to this work. The Expert Group would include representatives from UN agencies, national environmental and statistical authorities, space agencies, scientific bodies, standard-setting organizations such as, International Organization for Standardization (ISO), International Telecommunication Union (ITU), Open Geospatial Consortium (OGC), Organization for the Advancement of Structured Information Standards (OASIS) and World Wide Web Consortium (W3C), and coordination platforms such as CODATA, GEO and InforMEA. Activities would include:

- identifying existing data standards fit for global, cross-domain interoperability in the environmental data ecosystem and pinpointing core gaps and inconsistencies across different domains;
- creating guidance for coherently integrating domain-, region-, or nation-specific standards and data into the data ecosystem, without compromising global interoperability;
- drawing on open-source governance models (e.g. STAC) to guide the development of practical, community-maintainable guidance and reference implementations for harmonizing data formats, metadata schemas and semantic classifications, and building converters or adapters for existing datasets;
- promoting alignment of API designs with open standards and develop shared tools for integrating legacy systems and enabling real-time and on-demand data flows;
- coordinating with related initiatives, including the UN Transparency Protocol, the UNEP Finance Initiative, UNEP Life Cycle Initiative and the UN Ocean Decade's Corporate Data Group to support convergence between corporate and public environmental data infrastructures;
- providing technical inputs and reference materials to inform capacity-building efforts at regional and national levels, helping to align training and technical support with r interoperability standards.

3.5 Intervention point 5: Ensuring credible product and corporate sustainability disclosures

Why this is a priority

Environmental data are increasingly used not only to monitor ecosystem trends and inform policy implementation but also to determine market access, monitor supply chains, support corporate sustainability claims, inform pricing and taxation (e.g. carbon border adjustments), and enable compliance with emerging international and national regulations. Governance of sustainability disclosures requires activity at five levels, from product-level life cycle assessments to national and international policy frameworks (Table 3.1).

Despite steady advances in recent years, the overall system for generating, managing and using product sustainability data remains fragmented, with significant gaps and inconsistencies within and across these layers. For example, while regulators (Level 1) are advancing new disclosure mandates, they are often doing so in the absence of well-defined data infrastructures (Level 4) and harmonized sectoral baselines (Level 3), making consistent implementation and comparability difficult to achieve. Similarly, many digital disclosure tools and product information systems (Level 2) rely on life cycle assessment (LCA) data to populate key environmental indicators such as carbon footprints, resource use and pollution metrics, yet the underlying data (Level 5) often varies widely in scope, quality and methodology, limiting comparability. Meanwhile, digital data assurance mechanisms, such as automated validation tools or digital monitoring, reporting and verification (MRV) systems, can reduce verification costs and improve confidence in data points but are not yet widely integrated into disclosure workflows.

Table 3.1 Five levels of sustainability disclosure infrastructure

Level	Type	Purpose	Examples
1. Regulatory and policy frameworks	Mandates and goals	Define what sustainability disclosures are required or encouraged	EU Corporate Sustainability Reporting Directive, green procurement mandates
2. Disclosure systems and tools	Digital tools and platforms	Communicate environmental performance of products to markets and authorities	Digital Product Information Systems (e.g. EU Digital Product Passport), eco-labels
3. Sectoral baselines and reporting rules	Standardized rules and metrics	Ensure consistency and comparability of disclosures within and across sectors	EU Product Environmental Footprint Category Rules, WWF Codex Planetarius
4. LCA methodologies and databases	Methods and data infrastructure	Provide technical guidance and consistent data for assessments	UNEP's GLAM and GLAD (metadata and nomenclature work)
5. Product-level LCA studies	Individual assessments	Generate environmental performance data for specific products	LCA of T-shirt, phone, fertilizer, etc.

UNEP and its partners already play important roles through initiatives such as the Life Cycle Initiative (Level 4), the UNEP Finance Initiative (levels 1 and 3), the Global Framework for Digital Product Information Systems and the UN Transparency Protocol (Level 2). But enabling a coherent and trusted global system for sustainability disclosures, will require coordinated action across all levels of the disclosure value chain.

What success would look like

By 2035, product sustainability disclosures are consistent, credible and widely adopted across sectors, supported by a coherent system of guidance data and tools.

- Governments and international bodies have established clear policy frameworks that require or incentivize product-level sustainability disclosures. These frameworks are aligned with global targets and supported by consistent product-level metrics.
- Digital disclosure tools and product information systems operate under shared governance rules and interoperability standards. Platforms use harmonized inputs and provide clear, verifiable indicators for consumers, regulators and supply chains.
- A sector–impact materiality matrix guides disclosure priorities, identifying which environmental impacts are most relevant for each sector based on risk, significance and policy relevance.
- Sectoral baselines define minimum disclosure requirements, underpinned by a set of core variables, definitions and methodological assumptions. These ensure consistent and comparable reporting across tools, schemes and jurisdictions. Supply chain actors and SMEs are supported through tools, templates and training aligned with these baselines.
- LCA methodologies, databases and product-level studies are aligned and interoperable. A foundational but comprehensive set of open-access LCA data supports basic assessments, with broader datasets made accessible and interoperable through harmonized metadata and formats.
- Digital tools and governance protocols, such as selective redaction standards and mass-balance accounting, support secure and confidential data sharing without compromising transparency.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Establish or strengthen non-financial reporting requirements; align regulatory mandates with disclosure baselines and disclosure protocols; integrate consistent sustainability metrics (based on LCA) into procurement and trade policies, and monitoring frameworks.
International / regional organizations	Define overarching sustainability targets shaping national policies and actions; support the development and uptake of interoperable digital product information systems and LCA data and methods infrastructures, such as a global LCA platform; promote cross-border alignment and capacity-building.
Private sector	Participate in development of baselines, methodologies and digital disclosure tools; align reporting systems and certification schemes with shared guidance; promote uptake across supply chains; provide feedback on feasibility and sector-specific needs.
Scientific and technical bodies	Contribute expertise on methodologies and metrics; support validation and alignment with international standards (e.g. ISO, ITU, UN/CEFACT); develop open-access data systems and guidance for assessments.

UNEP's contribution

Member States could mandate UNEP to support efforts to strengthen the global system for product sustainability disclosures, with a particular focus on **developing sector-specific environmental data baselines and improving the accessibility and interoperability of LCA methodologies and databases.** This work would build on UNEP's existing initiatives and be carried out in collaboration with international and regional partners. Activities could include:

- Undertaking a mapping of existing product-level disclosure tools, methodologies and metrics, including voluntary frameworks, regulatory requirements and industry-led initiatives, to identify gaps, overlaps and opportunities for alignment.
- Convening expert working groups to define core environmental metrics, impact categories and methodological rules for high-impact sectors where no credible global baseline yet exists (e.g. textiles, electronics, chemicals).
- Ensuring that these baselines are aligned with international goals and processes (e.g. the Sustainable Development Goals, MEAs, Taskforce on Nature-related Financial Disclosures (TNFD)) and compatible with technical standards and infrastructures (e.g. ISO, ITU, UN/CEFACT), while driving harmonization among existing standards.
- Facilitating the development of a global LCA platform fostering data interoperability protocols, including standardized nomenclature, metadata structures and documentation formats, building on ongoing work under UNEP's Global Life Cycle Impact Assessment Method (GLAM) and Global LCA Data Access Network (GLAD) initiatives.
- Develop guidance for integration of sectoral baselines into certification schemes, regulatory frameworks, product-level disclosure systems and environmental monitoring platforms.
- Support uptake and capacity-building by working with regional and international partners such as UNECE and the UN Transparency Protocol to pilot implementation and promote adoption.

UNEP's role would focus on global coordination, technical guidance development and the creation of enabling infrastructure such as the Global LCA Platform and interoperability protocols. Member States and implementation partners would lead piloting, capacity-building and integration of tools into national or sectoral systems.

3.6 Intervention point 6: Delivering federated access to environmental data

Why this is a priority

Environmental data must be accessible, reliable and interoperable to support urgent action on the triple planetary crisis. Yet concerns over sovereignty, quality, privacy and commercial interests often limit data sharing, especially across borders and sectors. Centralized models can intensify these tensions, leading to fragmentation and inequities.

Federated data architectures offer a way forward. By enabling data to remain under the control of its original custodians, while still being discoverable and queryable via shared protocols, federated access balances local control with global collaboration. It also reduces redundancy by enabling query-based integration rather than duplicative storage, improving overall data stewardship and decreasing costs. Indeed, as highlighted across Chapter 2, federated data governance supports all five pillars of GEDS:

- Governance: upholding data sovereignty and enabling ethical, co-designed access, in accordance with the FAIR, TRUST and CARE principles, including respect for Indigenous rights through Free, Prior and Informed Consent (FPIC).
- Data quality: maintaining provenance and trust in source data.
- Interoperability: connecting systems via aligned APIs and metadata.
- Accessibility: reducing needless duplication and infrastructure costs while expanding reach.
- Capacity: enabling modular participation by low-resource actors.

Examples like GBIF, OBIS, the Ocean Data and Information System (ODIS) and the European Open Science Cloud (EOSC) show that federated models can scale regionally and globally while respecting data ownership. Regional initiatives such as the EU's Common Data Spaces, Gaia-X, and Destination Earth also demonstrate practical federated architectures and governance models that can inform global implementation. This underscores that such approaches can be expanded and replicated across contexts. However, key gaps remain. Many local datasets are still siloed, cross-domain integration is limited and governance models for sensitive or commercial data are underdeveloped. Few existing platforms enable real-time, AI-ready access to federated datasets. Prioritizing federated access can unlock an environmental data ecosystem that is both inclusive and globally connected, enabling faster, fairer and more effective decision-making. Furthermore, by drawing on data from multiple sources without centralizing it, a federated approach increases transparency and allows cross-validation of information, helping to verify data quality across the network.

What success would look like

By 2035, federated access is widely adopted as a foundational model for inclusive and scalable environmental data sharing. For example:

- Countries and other stakeholders across all regions are participating in federated data ecosystems that respect data sovereignty while enabling cross-border access and collaboration.
- National data platforms are interoperable by design, using common APIs and metadata standards to allow secure, query-based access without transferring raw data.
- Federated governance protocols (e.g. consent frameworks, data licensing agreements, ethical AI safeguards, access tiers) are integrated into environmental data strategies and institutional processes, as well as the UNEP Data Governance Policy.
- Regional and global federated nodes link platforms like GBIF, OBIS, ODIS, WIS 2.0 and national systems, enabling near real-time integration of biodiversity, climate, pollution and land-use data.
- Private-sector actors contribute environmental, LCA and ESG data to federated networks through data trusts and secure access mechanisms, supporting transparency without compromising confidentiality.

- Federated infrastructure supports early warning systems, monitoring frameworks and reporting under the SDGs and MEAs, even in low-resource settings, through modular, low-bandwidth-compatible tools.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Integrate federated access into national environmental data strategies, ensuring alignment with FAIR, TRUST and CARE principles; invest in interoperable, API-enabled data platforms and establish protocols that allow for tiered or consent-based access to sensitive datasets.
Indigenous and local communities	Co-develop federated data sharing protocols that reflect cultural values; protect knowledge systems and uphold data sovereignty, including the right to withhold or condition access based on Free, Prior and Informed Consent (FPIC).
Regional organizations	Support the development of regional federated nodes and harmonize technical standards across borders; facilitate peer learning, data diplomacy and shared infrastructure investment.
Private sector	Align ESG and sustainability reporting tools with federated access principles; participate in data trusts and other secure-sharing mechanisms, ensuring that proprietary or commercially sensitive data can be accessed while maintaining confidentiality.
Multilateral organizations and donors	Fund federated infrastructure development, especially in low-resource settings; promote federated principles as part of broader digital public goods strategies and align reporting and monitoring frameworks with interoperable, federated data flows.

UNEP's contribution

Member States could mandate UNEP to **develop the World Environment Situation Room (WESR) as a federated data access platform that enables Member States and other stakeholders to contribute and access environmental data without relinquishing control (for instance, via interconnected national and regional nodes)**, using shared metadata standards, APIs and consent-based access protocols, and in accordance with data quality standards and the UNEP Data Governance Policy. Activities would include:

- Ensuring interoperability with existing global platforms (e.g. GBIF, OBIS, Copernicus, ODIS, GEO), as well as MEA-related systems such as InforMEA and MEA clearing houses, by aligning WESR with open standards such as DCAT, STAC, and ISO 19115, enabling data exchange and integration.

- Facilitating the creation of national and regional WESR "nodes" that allow Member States to host and analyze their data locally while still contributing to the global system. This approach preserves data sovereignty through clear licensing and consent controls, and can build on existing open-source solutions (such as ESA's pilot codebase) to accelerate implementation and reduce costs.

- Cataloguing relevant data services to enhance discoverability. At a minimum, this would take the form of a UNEP-endorsed, centralized inventory of environmental data resources. Over time, this could evolve into a federated catalogue supporting distributed search and access across multiple platforms through shared metadata standards and APIs.
- Exploring links to intellectual property management systems and blockchain technologies to enhance traceability, data provenance, and accountability across federated environments.
- Establishing user-centered tools within WESR, enabling interactive analysis, visualization and storytelling across distributed datasets to support evidence-based policy and public engagement.
- Implementing robust governance protocols, including ethical safeguards, data quality controls and feedback loops to uphold FAIR, TRUST and CARE principles across federated data flows.
- Securing sustainable financing for WESR development and maintenance, including open-source or proprietary tools, staffing, infrastructure upgrades and user support systems.

UNEP's role would focus on developing the core platform, ensuring global interoperability and providing shared tools and services. Member States and other partners would support national and regional implementation, thematic application development and long-term institutional integration.

3.7 Intervention point 7: Promoting equitable access to essential environmental data

Why this is a priority

Despite rapid advances in environmental monitoring and digital infrastructure, equitable access to essential environmental data remains a systemic challenge. These are minimum sets of datasets needed to monitor environmental change and inform decision-making, such as key data on land cover, pollution levels, emissions inventories, biodiversity trends and sustainability indicators. At present, many datasets are difficult to find, fragmented across platforms, or locked behind paywalls, restricted licenses or proprietary platforms. This disproportionately affects researchers, policymakers and communities in low- and middle-income countries, who often lack the technical or financial capacity to access and integrate critical information.

Some regions, such as the EU, have begun mandating the release of "high-value datasets" – such as high-resolution satellite imagery, emissions baselines or product-level sustainability disclosures – recognizing their critical role in addressing environmental challenges. However, such policies remain limited globally, and the costs of acquisition, storage and management remain prohibitive for under-resourced actors.

Meanwhile, commercial interests increasingly shape who can access what data and reliance on private infrastructure raises concerns about vendor lock-in and long-term affordability. Even when datasets are publicly available, poor design, missing metadata and inaccessible interfaces limit their usability, especially for local authorities, civil society groups and non-expert users. As a result, the environmental data ecosystem risks deepening existing inequities, where only well-resourced actors can benefit from the full potential of data-driven decision-making.

What success would look like

By 2035, equitable access to environmental data is embedded in global digital infrastructure and governance. For example:

- A globally agreed set of essential environmental datasets, including land cover, emissions, biodiversity and pollution indicators, are openly or affordably available through trusted, interoperable platforms, with standardized metadata, APIs and licensing terms.
- All countries and communities, including those with limited financial or technical resources, can access and use environmental data for decision-making, reporting and emergency response, with dedicated support for marginalized and underrepresented groups.
- User-centered platforms are designed for both expert and non-expert users, offering intuitive interfaces, multilingual options and tools for exploration, analysis and storytelling.
- Sensitive and strategic datasets are governed through transparent protocols that balance access, privacy and risk, including tiered access, licensing frameworks and Indigenous data safeguards.
- Long-term funding and coordination mechanisms sustain open access, support repository maintenance and ensure the continuous availability, quality and usability of high-impact datasets as global public goods.

Needed actions from key stakeholders

Stakeholder	**Needed actions**
Governments	Adopt open data policies for publicly funded environmental information; apply standard open licenses (e.g. CC BY); reduce legal barriers to access; invest in national platforms that support local actors; release high-value environmental datasets through open data portals and standardized machine-to-machine interfaces.
Data providers	Offer essential datasets under open or fair-use licenses (e.g. Creative Commons); adopt common standards for metadata and access (e.g. DCAT, STAC); provide data in open formats (e.g. CSV, RDF); develop tiered or subsidized models that enable broader public benefit.
Regional and multilateral organizations	Coordinate equitable data access across borders; promote shared frameworks for interoperability, affordability, governance; =support regional infrastructure and federated data hubs, particularly for transboundary and high-impact datasets.
Funding partners and donors	Support sustainable financing for open access to environmental data, including infrastructure, licensing and training, and embed data equity

	and accessibility in broader environmental and digital development funding strategies.

UNEP's contribution

Member States could mandate UNEP to lead a multi-stakeholder process to **explore options for establishing a Global Environmental Data Utility (or a connected and interoperable set of regional utilities)**, which would establish a shared policy and financing mechanism to ensure affordable, equitable access to essential environmental data, particularly for countries in the Global South. UNEP's role would centre on coordination, policy design and technical scoping through activities such as leading consultations, mapping data access models, identifying priority datasets and developing prototype mechanisms. Member States, regional organizations and other partners would take the lead on operationalizing the utility, including formalizing participation through agreements, managing infrastructure and service delivery, and establishing and funding mechanisms to cover access costs.

Unlike technical platforms such as WESR, the utility would focus on negotiating and harmonizing access arrangements across key datasets, whether public, private or scientific, and developing sustainable funding models to cover associated licensing or delivery costs. Its purpose would be to enable low- or no-cost access to high-impact datasets (e.g. land cover, pollution, emissions, ESG data) that are otherwise financially or administratively out of reach for under-resourced actors.

The utility would operate through existing platforms, rather than replacing them. It would establish a common policy framework for access and affordability, and ensure that these datasets can be discovered and accessed via trusted gateways such as WESR. UNEP's role would be to coordinate consultations, assess institutional models and identify priority datasets and financing approaches in collaboration with Member States, data providers and funding partners. This would help remove systemic barriers to data equity, while advancing the broader goal of a trusted, inclusive and accessible global environmental data ecosystem.

UNEP could build on existing models such as the Development Data Partnership (see Annex III, Box 4.2), a collaboration between international organizations and leading technology companies that facilitates responsible and efficient use of third-party data (e.g. mobility, geospatial, environmental data) in support of development goals. The partnership provides legal and technical frameworks that enable access to private-sector datasets for over 400 projects, while working to make methods and code openly available for broader reuse.

3.8 Intervention point 8: Building needed capacities – human, institutional and technical

Why this is a priority

Effective environmental data ecosystems depend on a blend of technical infrastructure, institutional frameworks and human capacities. Yet across many countries, especially low- and middle-income ones, critical gaps persist in all three areas. Outdated monitoring equipment, weak data governance and a shortage of skilled professionals all undermine the collection, analysis and use of environmental data.

Inadequate data security and protection measures further compromise trust, resilience and the safe use of environmental data systems.

Even where data exist, the lack of capacity to manage or interpret it can render it effectively unusable for decision-making. Skills in data science, geospatial analysis, AI and policy integration are scarce. Institutions struggle with staff retention, fragmented mandates and siloed systems. Without investment in both human and technical capacities, environmental data systems will remain fragile, fragmented and underutilized, with particularly severe consequences for those facing the greatest environmental risks.

What success would look like

By 2035, meaningful progress has been made in closing core capacity gaps across the global environmental data ecosystem, particularly in countries where resources have historically been limited. Key outcomes would include:

- Countries have developed national capacity development strategies for environmental data, aligned with their institutional priorities and environmental goals.
- Governments, institutions and communities increasingly have access to the skills, tools and support needed to generate and use environmental data in decision-making. Public institutions attract and retain skilled professionals through clear career pathways, adequate incentives and continuous training.
- Regional and international organizations coordinate capacity-building support, offering complementary training, tools and infrastructure investment in line with country needs.
- Environmental data science, governance and use are integrated into university curricula and professional training for policymakers, analysts and technical staff. Collaborative platforms, mentorship networks and regional knowledge hubs support peer learning and innovation.
- Public agencies, including in low-resource settings, have access to essential infrastructure and tools for managing and using environmental data. This includes increased availability of cloud-based platforms, open-source software, scalable storage solutions and remote sensing technologies.
- Data protection protocols are in place across platforms, including secure storage, access controls, encryption and compliance with national or international data security standards.

Needed actions from key stakeholders

Stakeholder	Needed actions
Governments	Integrate environmental data capacity-building into national development plans and budgets. Establish training pathways and incentives to attract and retain skilled professionals. Promote coordination across agencies to reduce duplication and address gaps.

International and regional organizations	Align and coordinate capacity-building initiatives to respond to country needs. Support regional knowledge hubs, peer learning platforms and toolkits, and provide funding or infrastructure support where needed.
Platform developers and data providers	Offer affordable and context-appropriate tools, platforms and services to public institutions. Support training on their use, share open-source solutions where possible, and work to improve interoperability and accessibility.
Funding partners and donors	Support long-term, flexible support for capacity-building across the data lifecycle. Prioritize under-resourced settings and invest in scalable infrastructure, open tools and locally led training initiatives. Encourage collaboration between public, private and academic sectors.
Academic and training institutions	Embed environmental data skills in higher education and vocational programmes. Develop open-access, modular curricula tailored to diverse local contexts and partner with governments and regional networks to support lifelong learning.

UNEP's contribution

To address capacity gaps effectively, Member States could mandate UNEP to implement two complementary actions: first, creating an **environmental data capability assessment framework** to help countries diagnose their needs and benchmark progress; second, to develop and deliver a **multi-stage capacity-development support model** aligned to those levels of maturity.

UNEP's role would focus on organizing, coordinating and selectively contributing to the development of tools and resources, in collaboration with regional and international partners. The aim would be to map, connect and adapt existing materials wherever possible, and to fill critical gaps where necessary. UNEP would work with partners to curate the core structure of the framework and would coordinate a shared platform for knowledge exchange. Implementation, contextualization and delivery of training would be led by Member States and by partners working through regional platforms and networks. Over time, the model would support a distributed, partner-led approach to capacity-building, embedded within broader digital development and environmental governance efforts.

Part 1: Capability assessment framework for national environmental data systems

UNEP could develop an "environmental data capability assessment framework" to help Member States evaluate their current capacities and identify priority needs in managing environmental data. The tool would function as a self-assessment checklist covering the broad range of themes across the five pillars of GEDS: data governance, data quality and provenance, interoperability, accessibility and affordability, and capacity-building. Inspired by models like the Software Capability Maturity Model, the framework would define progressive maturity levels, guiding countries from foundational to advanced capabilities. It could also include a skills gap and institutional readiness component to support targeted capacity building and track progress over time.

The framework would serve as a practical tool for countries to benchmark their capabilities, identify tailored support needs and inform national capacity development strategies. It would also provide a foundation for UNEP and partners to coordinate training, tools and technical assistance in line with countries' current positioning and goals.

Part 2: A multi-stage capacity-development model aligned with country needs

To help countries strengthen their environmental data systems in a structured and scalable way, UNEP could facilitate the development of a multi-stage capacity-development model. This would complement the capability assessment by offering practical guidance and tools aligned with progressive stages of capacity across the five pillars of GEDS. Recognizing that countries may be at very different stages of development across these pillars – strong in one area but still emerging in another – the framework would be designed for flexibility. It would allow institutions to access tailored support, rather than follow a one-size-fits-all path. This modular approach would enable targeted progress, encourage peer learning and help align capacity-building efforts with countries' environmental priorities and institutional realities.

The framework would provide a flexible structure for countries and institutions to identify their current level, prioritize areas for improvement and access relevant resources. Key components could include modular training content, templates and toolkits aligned with each stage and pillar; curated guidance and case studies; a repository of open-source tools and platforms, including those suited to low-resource environments; and peer learning and mentorship models, primarily delivered through regional organizations, academic networks and other implementation partners.

UNEP's role would focus on mapping, organizing and coordinating these efforts, helping to ensure alignment, reduce duplication and identify opportunities for synergies across initiatives. Where critical gaps are identified, UNEP could contribute to the development of new materials or support targeted training activities, within its mandate and resources. Over time, the framework would support a distributed, partner-led model of capacity-building, embedded within broader environmental and digital development initiatives. Table 3.2 provides a simple illustration of a multi-stage framework.

Table 3.2 Simplified illustration of a multi-stage framework for assessing and developing environmental data capacities

Stage 1: Environmental data initiation	Stage 2: Foundational systems	Stage 3: Coordinated systems	Stage 4: Integrated and applied data	Stage 5: Leadership and innovation
Countries face foundational gaps in institutional, technical and human capacity. Infrastructures are fragmented or absent. Data remains scattered, inconsistent or unavailable. • No coherent data strategy or coordinating authority. • Monitoring and data systems are ad hoc or donor driven. • Data are not standardized, digitized or interoperable. • Metadata and provenance practices are minimal or non-existent. • Critical infrastructure is lacking or obsolete, including in situ sensors, data centres, and reliable connectivity • Data literacy is limited; few trained professionals. • No security protocols or responsibilities defined.	Countries start building core capacities. Coordination begins, basic strategies and data ecosystems start to emerge. • Institutional mandates are clearer, but implementation remains limited. • Foundational monitoring and data management systems are operational in some sectors. • Metadata standards and QA/QC protocols are emerging. • Basic infrastructure, e.g. calibrated monitoring equipment and cloud storage, is deployed or planned. • Government staff are engaged in basic training. • Institutions participate in regional learning networks. • Data protection is ad hoc with limited awareness of risks.	Countries are actively implementing data strategies. Systems become more standardized, coordinated, and interoperable. • A national environmental data strategy or policy roadmap exists. • National and sectoral data platforms are interoperable and supported by scalable infrastructure for data exchange / integration. • Metadata, QA and provenance are embedded in workflows. • Policies promote open access and responsible data use. • Institutions begin to adopt semantic standards and APIs. • Regular capacity development occurs through training programmes and partnerships. • Security protocols and roles are formalized.	Environmental data are embedded in national development processes, policymaking and reporting. • Data governance frameworks are institutionalized and budgeted. • Environmental data are linked to climate, health, agriculture and other sectors. • AI, remote sensing and machine-readable metadata are in use. • Public platforms are open, user-oriented and updated in real-time. • Infrastructure is resilient and enables real-time analytics, cross-sector integration, and decentralized access. • Universities etc. produce highly skilled professionals. • Robust data protection policies exist, compliant with cybersecurity standards.	Countries are regional or global leaders, contributing to data innovation, global standards and peer learning. • National data systems are federated with regional and global platforms. • Advanced governance frameworks address ethics, sovereignty, AI. • Countries lead or contribute to development of global standards. • Environmental data supports innovation, circular economy and green tech. • Advanced infrastructure, e.g. sovereign cloud platforms, AI-powered decision systems, green data centres. • Countries mentor and support peers through South-South/North-South collaboration. • Security and ethical safeguards are embedded across the data lifecycle.
Goal: Establish basic foundations across governance, infrastructure, knowledge and skills.	**Goal**: Build minimum viable capacity across all pillars.	**Goal:** Scale and consolidate systems, tools and human capacity.	**Goal**: Integrate systems across sectors, ensure long-term sustainability and impact.	**Goal**: Sustain innovation, contribute globally, support others.

4 From vision to action: implementing GEDS

The Global Environmental Data strategy presents a bold vision: achieving a trusted, inclusive, interoperable and accessible environmental data ecosystem by 2035. Delivering this vision will require concerted efforts by a broad array of stakeholders, including national governments, international organizations, scientific bodies, civil society and the private sector. No single actor can achieve the needed transformation. But UNEP is uniquely positioned to help drive forwards change. If mandated by Member States, UNEP can take on a vital enabling role: making full use of its convening power, scientific credibility and experience in developing essential tools, guidance and frameworks to support collective action.

Chapter 3 identifies eight actions that UNEP and its partners could implement to catalyse change at each of the intervention points. The actions are summarized in Table 4.1, with key activities clustered into three phases:

- Phase 1: Foundations (three years) – focused on scoping, stakeholder engagement and piloting
- Phase 2: Acceleration and upscaling (three years) – rolling out tools and guidance, expanding reach and refining approaches
- Phase 3: Mainstreaming (four years) – embedding GEDS principles and tools into national and institutional systems

Table 4.1 also contains an indicative budget for each action. These activities and budget estimates are set out in more detail in Annex I. The figures are indicative and partly contingent on decisions about implementation models and ambition levels. As such, they are intended to provide a reasonable basis for planning and resource mobilization, rather than a rigid prescription.

4.1 A flexible and adaptive implementation model and funding mechanism

Rather than a fixed blueprint, UNEP proposes a flexible, adaptive model for implementation. Each action is structured in three broad phases, but progress will not necessarily be linear or uniform across the different workstreams. A Steering Committee comprising Member States and key partners would provide strategic direction, continually review implementation and prioritization, and ensure that GEDS actions are aligned and connected with other global processes and stakeholders.

This modular, iterative model draws inspiration from similar UN-led frameworks such as the Global Digital Compact, which emphasize phased delivery, Member State oversight and multi-stakeholder engagement to guide implementation over time. This approach would allow UNEP and its partners to respond to emerging needs and feedback, for example prioritizing actions on data quality, interoperability and capacity-building in early years, while broadening the focus in later phases. It also supports coordination across complementary initiatives and builds space for innovation, learning and course correction.

Table 4.1 UNEP actions to realize the GEDS vision and indicative budget 2026-2035

Enabling actions	Phase 1: Foundations 3 years	Phase 2: Acceleration and upscaling 3 years	Phase 3: Mainstreaming 4 years	Indicative budget 2026 - 2035
1. Developing national environmental data strategies and policies.	Co-develop guidance framework, conduct consultations, and pilot in 3-5 countries.	Support regional adaptation and uptake, provide technical assistance and training, and expand the toolkit.	Promote broader roll-out through peer learning, update tools and integrate with digital strategies.	$4.35 million
2. Strengthening environmental data quality and trust frameworks.	Design a global quality assurance facility, draft a classification system, pilot assessments.	Launch and operate voluntary assessment service, refine tools and expand to new domains.	Expand assessments to new domains, refine tools and promote uptake through platforms and partnerships.	$3.65 million
3. Aligning around essential variables and shared scientific standards.	Map existing frameworks, identify gaps and overlaps, and initiate development of a global overview.	Co-develop model protocols and guidance, pilot in countries or regions, and launch open-access platform.	Promote global adoption of variables and protocols, update guidance and support institutionalization.	$10.3 million
4. Harmonizing interoperability standards for environmental data.	Convene expert group, map existing standards, identify inconsistencies and begin drafting technical guidance.	Finalize and publish guidance, promote alignment through workshops and tools.	Monitor uptake and refine guidance, support standard updates and align platforms and tools.	$4.3 million
5. Ensuring consistent and credible product sustainability disclosures.	Undertake global stocktake, establish expert working groups for priority sectors and launch consultations.	Finalize and publish sectoral guidance, pilot implementation in selected sectors or supply chains.	Scale up use of sectoral baselines, integrate into disclosure systems and support institutionalization.	$12.7 million
6. Developing WESR as a federated platform that maintains data sovereignty	Define governance models, identify pilot partners and outline technical architecture and API requirements.	Pilot federated access infrastructure, align APIs and metadata, and implement governance protocols.	Expand federated access infrastructure, strengthen governance and align with global platforms.	$5.1 million
7. Promoting equitable access to essential environmental data.	Convene multi-stakeholder group, map access models and dataset barriers and define access criteria.	Develop policy and governance framework, explore financing options and prepare for pilot rollouts.	Expand access utility, formalize participation and institutionalize governance.	$8.9 million
8. Building needed capacities - human, institutional and technical.	Develop the capability assessment framework with pilot countries and map training and platform gaps.	Roll out capability framework, launch phased support model and share resources through peer networks.	Support integration of tools and training, promote regional knowledge-sharing and evaluate impact.	$5.9 million
Indicative budget	$15 million	$15 million	$25 million	**$55.2 million**

The proposed funding mechanism would mirror this flexible structure. Rather than a rigid, earmarked model, UNEP would work with partners to establish a consortium-based funding mechanism that enables phased investment aligned to evolving priorities. An indicative budget of approximately $15 million is proposed for the first three years (Phase 1), covering scoping, piloting and stakeholder engagement.

Funding could be pooled through a UNEP-hosted trust fund or aligned facility, with contributions from Member States, multilateral partners, philanthropic organizations and private sector actors. The mechanism would support catalytic investment in tools, platforms, capacity development and governance processes, with a strong emphasis on equity, South-South cooperation and long-term sustainability. More information on the design and administration of this mechanism, drawing on lessons from comparable initiatives, is set out in Annex I.

4.2 Conclusion: turning ambition into impact

The Global Environmental Data Strategy sets out an ambitious but achievable vision for transforming how environmental data are governed, shared and used. Realizing this vision will depend on strong political will, coordinated action across institutions and sectors, and sustained investment over time. While UNEP's proposed actions offer a practical and catalytic path forward, their success will ultimately depend on deep collaboration and shared commitment across the global community.

Member States now have an opportunity to shape and support this collective effort. By mandating UNEP to take forward the actions outlined here, and by contributing resources, expertise and political support, they can help ensure that high-quality, accessible and trusted environmental data become a global public good, supporting sustainable development, accountability and environmental justice worldwide.

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Annex I Proposed approach for implementing and funding UNEP actions

The present annex provides additional detail on the potential UNEP contributions introduced in Chapter 3 of the UNEP Global Environmental Data Strategy (GEDS). These actions represent a set of options that Member States could mandate and resource UNEP to implement in support of the GEDS intervention points. While Chapter 3 outlines the purpose and rationale for each action, this annex provides more detail on the activities and costs associated with each action (Section I.1), as well as proposals for an agile and stakeholder-led implementation model and funding mechanism.

The proposed approach assumes a lean and focused delivery model. UNEP's role is rooted in its core strengths as the world's leading authority on the environment in convening and coordinating stakeholders; facilitating science-policy dialogue and knowledge exchange; making critical, high quality environmental data accessible on UNEP platforms; and designing globally applicable frameworks and tools to guide and enable effective data governance. UNEP would not be responsible for country-level implementation beyond engaging pilot countries to collect feedback during design and development phases. Activities such as piloting and uptake are expected to be led by governments and implementation partners (e.g. development agencies, multilateral banks, regional bodies), using UNEP-developed resources as inputs.

To clarify this distinction, budgets are presented in two parts. The first relates to estimated costs for UNEP actions (e.g. framework development, stakeholder consultations, digital platforms, coordination). These assume that delivery will be based on lightweight, digital-first approaches, including online meetings and open-source tools, to minimize overheads and environmental impacts, while maximizing engagement.

The second part of cost estimates provides for a core set of piloting and uptake activities. These cover representative efforts to apply the tools in selected countries or contexts, with the goal of validating approaches and generating lessons. Support for wider uptake would depend on the provision of additional resources by Member States and implementation partners.

Together, the information presented here aims to inform Member State decisions on the scale and scope of UNEP actions, and how these efforts might be phased and resourced through multilateral cooperation.

I.1 Indicative timeline, milestones and costs for UNEP actions

I.1.1 Action 1: Developing a guidance framework for national environmental data strategies

A UNEP "Guidance Framework for Environmental Data Governance" would support countries in creating and strengthening national environmental data strategies and policies by 2035. The framework would be co-developed with Member States, regional organizations and relevant partner to ensure that it reflects the needs and capacities of diverse contexts.

UNEP's role would focus the design and delivery of this global framework, which would:

- set out core governance principles, including sovereignty, privacy, ethics, security and internationally recognized standards such as FAIR, TRUST, CARE and openness;

- outline options and examples for integrating diverse data sources, including citizen science, into national data strategies;
- provide adaptable templates and tools for strategy development, data classification, inter-agency coordination and metadata and interoperability standards;
- serve as a baseline of best practices that UNEP can help tailor to specific national and regional contexts;
- address the environmental data needs of the private sector by identifying shared public–private data priorities, promoting open access to foundational datasets and encouraging business participation in national data governance processes;
- support progressive realization across countries at different levels of institutional capacity, with differentiated pathways and implementation support mechanisms.

UNEP would not be responsible for implementing national strategies, other than engaging with selected pilot countries during the framework's design phase to test approaches, collect feedback and refine the framework. Broader uptake and implementation would be led by governments and other partners, such as regional organizations or development agencies. Such partners would be responsible for delivering technical assistance, adapting tools to national contexts and supporting institutional integration.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Framework development (3 years)	Expert group coordination and drafting of guidance framework	UNEP	$250,000
	Development of templates and adaptable tools	UNEP	$200,000
	Consultations and piloting in c. 3-5 countries representing different institutional and capacity contexts	Partners*	$700,000
	Analysis of feedback and refinement of the framework	UNEP	$150,000
	Phase 1 subtotal		**$1.1 million**
Regional uptake and capacity support (3 years)	Supporting adaptation to regional contexts and legal frameworks	Partners	$300,000
	Technical assistance to the first wave of countries	Partners	$1,000,000
	Expansion of toolkit	UNEP	$200,000
	Development of e-learning and trainer-of-trainer tools	UNEP	$250,000
	Phase 2 subtotal		**$1.45 million**

Broader roll out and learning (4 years)	Support roll-out through regional peer learning networks and South-South exchange	Partners	$800,000
	Facilitate cross-regional consultations and document implementation case studies	UNEP	$250,000
	Update of the framework	UNEP	$250,000
	Phase 3 subtotal		**$1.1 million**

Total indicative budget (2026–2035): $4.35 million

UNEP activities: $1.55 million

Member State and development partner activities: $2.8 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.2 Action 2: Establishing a global mechanism for environmental data quality assurance

A UNEP-led global mechanism for environmental data quality assurance would offer a pragmatic, voluntary service to build trust in environmental data and promote best practices in data collection, processing and use. Data providers could voluntarily submit their datasets for assessment, receiving a UNEP-backed quality label that signals credibility.

The mechanism would adopt an incremental approach, offering structured but lightweight support to governments, researchers and businesses seeking to assess or demonstrate the reliability of their datasets. The initiative would draw on and complement existing standards, such as the FAIR and TRUST principles, ISO 8000 quality standards and repository certifications like CoreTrustSeal, focusing specifically on the environmental domain and applying these principles to assess specific datasets.

As part of this function, UNEP could convene expert groups to co-develop a flexible classification system that defines levels of data quality and recommended application contexts, for example whether a dataset is suitable for policy enforcement, long-term trend analysis or exploratory research. This system could incorporate indicators for fitness-for-purpose and certainty levels, helping users interpret and compare datasets with greater confidence.

To support data providers, a scoring system (e.g. 1 to 5 stars) could also be used to help data providers identify what specific improvements are needed to enhance trust, usability and policy relevance. The design of the system could draw on elements of the EU's Open Data Maturity Framework (EU, 2025).

By enhancing transparency and interoperability without imposing rigid mandates, this mechanism would help embed quality assurance more deeply across the data ecosystem. UNEP's role would focus on the design and refinement of the mechanism, including piloting in selected domains, coordination of expert consultations, and development of templates and guidance materials. Operational delivery of the voluntary assessment service, as well as technical assistance to data providers, would be led by Member States and implementation partners.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Design and piloting (3 years)	Design global mechanism for environmental data quality assurance	UNEP	$350,000
	Convene expert groups to draft classification system and use cases	UNEP	$250,000
	Identify pilot domains and conduct pilot assessments and consultations	UNEP/ partners	$500,000
	Draft initial guidance materials and templates explaining the framework, assessment process, submission requirement, etc.	UNEP	$250,000
		Phase 1 subtotal	**$1.35 million**
Launch and first-wave (3 years)	Establish and operationalize the voluntary assessment service	Partners	$500,000
	Provide technical assistance to early adopters	Partners	$400,000
	Refine tools and guidance based on user feedback	UNEP	$300,000
		Phase 2 subtotal	**$1.2 million**
Mainstreaming (4 years)	Expand to additional domains and use cases	UNEP	$450,000
	Promote uptake through platforms and peer learning mechanisms	UNEP	$350,000
	Update and mainstream guidance through global platforms and training resources	Partners	$300,000
		Phase 3 subtotal	**$1.1 million**

Total indicative budget (2026–2035): $3.65 million

UNEP activities: $2.45 million

Member State and development partner activities: $1.2 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.3 Action 3: Facilitating greater global alignment around essential variables and scientific standards

UNEP could be mandated to lead a global coordination initiative to strengthen the coherence, complementarity and **practical uptake of essential variables and indicators across environmental domains, anchored in rigorous "gold standard" methods for scientific data collection and assessment**. Rather than creating new variable frameworks, UNEP would work with partners to map, connect and support the adoption of existing efforts, while identifying gaps and enabling targeted improvements in underrepresented areas.

This process would begin with a comprehensive mapping of existing essential variable and indicator frameworks, such as the EBVs, ECVs, EOVs and relevant MEA indicators, including associated protocols and quality standards. UNEP would produce a synthesis overview to help countries and stakeholders navigate these efforts, understand how they align and identify practical entry points for implementation.

Where gaps or fragmentation exist, such as in areas like waste, land degradation or environmental governance, UNEP would convene expert groups to support the identification and definition of essential variables, as well as the co-development of model protocols, building where possible on existing scientific standards. In parallel, UNEP could facilitate adoption by developing toolkits and training modules, and coordinating with stakeholders already active in global monitoring and assessment.

Piloting of these protocols, delivery of technical training and integration into national systems would be led by Member States and development partners, using UNEP-developed resources as inputs. The focus would be on enabling coherent, policy-relevant and interoperable environmental monitoring systems, with UNEP acting as a steward and convener, fostering alignment across initiatives and helping translate variable frameworks into actionable data strategies.

UNEP could also work with the secretariats of the Rio Conventions to identify opportunities for streamlining and aligning core indicators across MEAs. This would reduce reporting burdens on countries, enhance coherence in tracking environmental commitments, and support integrated implementation of global frameworks.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Foundational analysis and framework design (3 years)	Map existing essential variable and indicator frameworks across domains	UNEP	$100,000
	Identify datasets that countries can prioritize to support multiple essential variables and policy-relevant indicators	UNEP	$150,000
	Analyze gaps, overlaps and opportunities for alignment	UNEP	$150,000
	Convene expert consultations in fragmented domains (e.g. land degradation, governance)	UNEP	$400,000
	Initiate development of global overview framework linking variables, indicators, and protocols	UNEP	$700,000
	Phase 1 subtotal		**$1.5 million**

Tool development and piloting (3 years)	Validate priority variables and co-develop practical protocols and guidance for data collection, classification and use in selected domains	UNEP	$1.5 million
	Pilot implementation in selected countries or regions, applying protocols within real data systems and national reporting processes	Partners	$2 million
	Develop and launch open-access repository for protocols and training resources	UNEP	$1.2 million
	Coordinate alignment with MEA frameworks and SDG indicator processes, including technical contributions to global harmonization	UNEP	$400,000
	Conduct technical training and peer exchange activities	Partner	$500,000
	Phase 2 subtotal		**$5.6 million**
Mainstreaming (4 years)	Expand to additional domains and use cases based on lessons from phase 2	UNEP	$500,000
	Promote uptake and mainstream guidance through platforms, partnerships, and peer learning	Partners	$800,000
	Maintain and periodically update the global framework and toolkits	UNEP	$450,000
	Facilitate institutional integration of the framework at national and regional levels through Member State leadership	Partners	$1 million
	Engage with global assessments and reporting mechanisms to embed harmonized variables	UNEP	$450,000
	Phase 3 subtotal		**$3.2 million**

Total indicative budget (2026–2035): $10.3 million

UNEP activities: $6 million

Member State and development partner activities: $4.3 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.4 Action 4: Convening an Expert Group on Environmental Data Interoperability Standards

Member States could mandate UNEP to **convene an Expert Group on Environmental Data Interoperability to coordinate and provide consistent guidance on the implementation of**

sustainable interoperability data architectures across the environmental data ecosystem. This would include identifying viable data formats, metadata structures, semantic resources and machine-to-machine exchange across environmental domains. The focus would not be on developing new standards but rather agreeing to prioritize a selection across all domains, noting where extensions are needed.

The Expert Group would engage with and build on existing initiatives led by, for example, the Committee on Data of the International Science Council (CODATA), the Group on Earth Observations (GEO), GBIF, OBIS, UNESCO-IOC and the World Meteorological Organization (WMO). It would include representatives from UN agencies, national environmental and statistical authorities, space agencies, scientific bodies, platform developers and standard-setting organizations such as CODATA, International Organization for Standardization (ISO), International Telecommunication Union (ITU), Open Geospatial Consortium (OGC) and World Wide Web Consortium (W3C). Activities would include:

- identifying existing data standards fit for global, cross-domain interoperability in the environmental data ecosystem and pinpointing core gaps and inconsistencies across different domains;
- creating guidance for coherently integrating domain-, region-, or nation-specific standards and data into the data ecosystem, without compromising global interoperability;
- drawing on open-source governance models (e.g. STAC) to guide the development of practical, community-maintainable guidance and reference implementations for harmonizing data formats, metadata schemas and semantic classifications, and building converters or adapters for existing datasets;
- promoting alignment of API designs with open standards and develop shared tools for integrating legacy systems and enabling real-time and on-demand data flows;
- coordinating with related initiatives, including the UN Transparency Protocol, the UNEP Finance Initiative, UNEP Life Cycle Initiative and the UN Ocean Decade's Corporate Data Group to support convergence between corporate and public environmental data infrastructures;
- providing technical inputs and reference materials to inform capacity-building efforts at regional and national levels, helping to align training and technical support with r interoperability standards.

UNEP would be responsible for convening the expert group, coordinating consultations and co-developing guidance and technical documentation. Governments, regional platforms, technical institutions and other partners would lead the development and piloting of reference implementations, contribute to training and outreach, and support dissemination and uptake. The work would follow a streamlined, collaborative model, emphasizing virtual engagement, open-source solutions and targeted technical contributions from partners to ensure broad participation and cost-effective delivery.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Scoping and drafting (3 years)	Convene Expert Group on Environmental Data Interoperability	UNEP	$300,000
	Identify existing standards, protocols and frameworks across domains suitable for use in a global data ecosystem, identifying key gaps and inconsistencies	Partners	$300,000
	Begin drafting technical guidance, including semantic translation, open API design and recommended (meta)data format specifications.	UNEP	$600,000
	Develop plan for reference implementations of interoperability modules for data ecosystem participation.	UNEP	$300,000
	Phase 1 subtotal		**$1.5 million**
Publishing, dissemination and demonstration (3 years)	Finalize and publish interoperability guidance; reference implementations to be developed and maintained by technical partners.	UNEP	$300,000
	Disseminate through international fora and regional workshops	Partners	$300,000
	Promote alignment through reference tools and open-source utilities (example APIs, data converters, templates, etc.)	UNEP / partners	$500,000
	Implement demonstration projects with partners	Partners	$500,000
	Phase 2 subtotal		**$1.6 million**
Mainstreaming (4 years)	Track uptake through partner reporting and engagement, and synthesize lessons to inform ongoing guidance	UNEP / partners	$300,000
	Support iterative refinement and periodic update of guidance and implementations	UNEP	$450,000
	Engage with standards bodies and developers for continuing alignment	UNEP	$450,000
	Phase 3 subtotal		**$1.2 million**

Total indicative budget (2026–2035): $4.3 million

UNEP activities: $2.8 million

Member State and development partner activities: $1.5 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.5 Action 5: Facilitating improvements to product sustainability disclosures

UNEP would coordinate efforts to strengthen the global system for product sustainability disclosures, with a particular focus on developing sector-specific environmental data baselines and improving the accessibility and interoperability of LCA methodologies and databases. This work would build on UNEP's existing initiatives and be carried out in collaboration with international and regional partners.

Activities could include:

- Undertaking a mapping of existing product-level disclosure tools, methodologies and metrics, including voluntary frameworks, regulatory requirements and industry-led initiatives, to identify gaps, overlaps and opportunities for alignment.
- Convening expert working groups to define core environmental metrics, impact categories and methodological rules for high-impact sectors where no credible global baseline yet exists (e.g. textiles, electronics, chemicals).
- Ensuring that these baselines are aligned with international sustainability goals (e.g. SDGs, MEAs, TNFD) and compatible with technical standards and infrastructures (e.g. ISO, ITU, UN/CEFACT), while driving alignment among the numerous existing standards.
- Facilitating the development of a Global LCA platform fostering data interoperability protocols, including standardized nomenclature, metadata structures and documentation formats, building on ongoing work under UNEP's Global Life Cycle Impact Assessment Method (GLAM) and Global LCA Data Access Network (GLAD) initiatives.
- Develop guidance for integration of sectoral baselines into certification schemes, regulatory frameworks, product-level disclosure systems and environmental monitoring platforms.
- Supporting pilot implementation, institutional uptake and capacity-building in collaboration with Member States, regional organizations and international partners such as UNECE and the UN Transparency Protocol.

UNEP's role would focus on global coordination, technical guidance development and the creation of enabling infrastructure such as the Global LCA Platform and interoperability protocols. Member States and implementation partners would lead piloting, capacity-building and integration of tools into national or sectoral systems.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Foundations and technical framework design (3 years)	Undertake global stock-take of disclosure tools, methodologies and metrics	UNEP	$400,000
	Establish expert working groups for high-impact sectors	UNEP	$600,000
	Begin development of LCA data interoperability protocols	UNEP	$1.2 million
	Initiate stakeholder consultations and priority setting	UNEP	$400,000
	Phase 1 subtotal		**$2.6 million**

Platform development, sectoral guidance and piloting (3 years)	Launch Global LCA Platform with open-access data infrastructure	UNEP	$1.5 million
	Finalize and publish sector-specific environmental data baselines	UNEP	$1.2 million
	Finalize LCA interoperability guidance	UNEP	$800,000
	Pilot integration in disclosure tools, certification systems and regulations	Partners	$1.2 million
	Develop training resources and implementation guidance	UNEP	$600,000
	Phase 2 subtotal		**$5.3 million**
Global uptake and mainstreaming (4 years)	Support broader roll-out at national, regional and sectoral levels	Partners	$2 million
	Review and update baselines and protocols through expert-led processes	UNEP	$600,000
	Support institutionalization and regulatory alignment	Partners	$1.2 million
	Deliver capacity-building and training programmes	Partners	$1 million
	Phase 3 subtotal		**$4.8 million**

Total indicative budget (2026–2035): $12.7 million

UNEP activities: $7.3 million

Member State and development partner activities: $5.4 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.6 Action 6: Developing WESR as a federated platform that maintains data sovereignty

Developing WESR as a federated data access platform would enable Member States and other stakeholders to contribute and access environmental data while retaining control and ownership, for instance through interconnected national and regional nodes. The platform would use shared metadata standards, APIs and consent-based access protocols, in accordance the UNEP Data Governance Policy and relevant data quality standards. UNEP's role would focus on developing the core platform, ensuring global interoperability and providing shared tools and services. Member States and other partners would support national and regional implementation, thematic application development and long-term institutional integration.

Activities would include:

- Ensuring interoperability with existing global platforms (e.g. GBIF, Copernicus, ODIS, GEO) by aligning WESR with open standards such as DCAT, STAC, and ISO 19115, enabling data exchange and integration.
- Facilitating the creation of national and regional WESR "nodes" that allow Member States to host and analyze their data locally while still contributing to the global system. This approach preserves data sovereignty (through clear licensing and consent controls) and can build on existing open-source solutions (such as ESA's pilot codebase) to accelerate implementation and reduce costs.
- Cataloguing relevant data services to enhance discoverability. At a minimum, this would take the form of a UNEP-endorsed, centralized inventory of environmental data resources. Over time, this could evolve into a federated catalogue supporting distributed search and access across multiple platforms through shared metadata standards and APIs.
- Exploring links to intellectual property management systems and blockchain technologies to enhance traceability, data provenance, and accountability across federated environments.
- Establishing user-centered tools within WESR, enabling interactive analysis, visualization and storytelling across distributed datasets to support evidence-based policy and public engagement.
- Implementing robust governance protocols, including ethical safeguards, data quality controls and feedback loops to uphold FAIR, TRUST and CARE principles across federated data flows.
- Securing sustainable financing for WESR development and maintenance, including open-source or proprietary tools, staffing, infrastructure upgrades and user support systems.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Completing WESR v. 1 (3 years)	Finalization of first phase of WESR, building on lessons learned from the 2025 pilot	UNEP	$2.6 million
	Phase 1 subtotal		**$2.6 million**
Developing user-centred applications (3 years)	Building interactive tools for data analysis, visualization and storytelling	UNEP	$900,000
	Supporting third-party development of thematic applications using WESR	Partners	$600,000
	Phase 2 subtotal		**$1.5 million**

Establishing federated nodes (4 years)	Supporting national and regional WESR nodes that enable local data hosting and control	Partners	$700,000
	Exploring links to intellectual property management systems and blockchain technologies for data traceability	UNEP	$300,000
		Phase 3 subtotal	**$1 million**

Total indicative budget (2026–2035): $5.1 million

UNEP activities: $3.8 million

Member State and development partner activities: $1.3 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.7 Action 7: Establishing a Global Environmental Data Utility to ensure affordable access to essential environmental data

A UNEP-led multi-stakeholder process would explore options for establishing a Global Environmental Data Utility (or a connected and interoperable set of regional utilities), which would establish a shared policy and financing mechanism to ensure affordable, equitable access to essential environmental data, particularly for countries in the Global South. Unlike technical platforms such as WESR, the utility would focus on negotiating and harmonizing access arrangements across key datasets, whether public, private or scientific, and developing sustainable funding models to cover associated licensing or delivery costs. Its purpose would be to enable low- or no-cost access to high-impact datasets (e.g. land cover, pollution, emissions, ESG data) that are otherwise financially or administratively out of reach for some actors.

The utility would operate through existing platforms, rather than replacing them. It would establish a common policy framework for access and affordability, and ensure that these datasets can be discovered and accessed via trusted gateways such as WESR. Collectively, this would help remove systemic barriers to data equity, while advancing the broader goal of a trusted, inclusive and accessible global environmental data ecosystem.

UNEP's role would centre on coordination, policy design and technical scoping through activities such as leading consultations, mapping data access models, identifying priority datasets and developing prototype mechanisms. Member States, regional organizations and other partners would take the lead on operationalizing the utility, including formalizing participation through agreements, managing infrastructure and service delivery, and establishing and funding mechanisms to cover access costs.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Foundational analysis and framework design (3 years)	Convene multi-stakeholder working group and establish secretariat	UNEP	$250,000
	Map access models, licensing practices and platform barriers	UNEP / partners	$200,000
	Identify high-impact datasets with constrained access	UNEP / partners	$200,000
	Develop initial criteria for prioritization and eligibility	UNEP	$150,000
	Design and validate data access utility concept and architecture	UNEP	$500,000
	Build and test prototypes for selected access mechanisms	Partners	$500,000
	Phase 1 subtotal		**$1.8 million**
Tool development and piloting (3 years)	Conduct regional dialogues and build partner commitments	UNEP	$500,000
	Finalize utility design, including access tiers and governance protocols	UNEP	$500,000
	Develop policy framework, accountability and financing models	UNEP	$500,000
	Pilot access arrangements for selected datasets	Partners	$800,000
	Coordinate integration with existing platforms and promote visibility	Partners	$500,000
	Phase 2 subtotal		**$2.8 million**
Scale up and mainstreaming (4 years)	Expand coverage to new domains, regions, and user groups	Partners	$1.2 million
	Formalize participation of data providers and users through agreements	Partners	$800,000
	Institutionalize governance, reporting, and dispute resolution systems	UNEP	$700,000
	Develop infrastructure and user support systems	Partners	$800,000
	Deliver access to priority datasets and maintain shared infrastructure under the utility framework	Partners	$800,000
	Phase 3 subtotal		**$4.3 million**

Total indicative budget (2026–2031): $8.9 million

UNEP activities: $3.3 million

Member State and development partner activities: $5.6 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.8 Action 8: Creating a capability assessment framework and a capacity-building model

To address capacity gaps effectively, the UN Environment Assembly could mandate UNEP to implement two complementary actions: first, creating an **environmental data capability assessment framework** to help countries diagnose their needs and benchmark progress; second, to develop and deliver a **phased capacity-building support model** aligned to those levels of maturity.

Part 1: Capability assessment framework for national environmental data systems

UNEP could develop an "Environmental Data Capability Assessment Framework" to help Member States evaluate their current capacities and identify priority needs in managing environmental data. The tool would function as a self-assessment checklist covering the broad range of themes across the five pillars of GEDS: data governance, data quality and provenance, interoperability, accessibility and affordability, and capacity-building. Inspired by models like the Software Capability Maturity Model, the framework would define progressive maturity levels, guiding countries from foundational to advanced capabilities. It could also include a skills gap and institutional readiness component to support targeted capacity building and track progress over time.

The framework would serve as a practical tool for countries to benchmark their capabilities, identify tailored support needs and inform national capacity development strategies. It would also provide a foundation for UNEP and partners to coordinate training, tools and technical assistance in line with countries' current positioning and goals.

Part 2: A phased capacity-development model aligned with country needs

To help countries strengthen their environmental data systems in a structured and scalable way, UNEP could facilitate the development of a Phased Capacity-Development Model. This would complement the Capability Assessment by offering practical guidance and tools aligned with progressive phases of capacity across the five pillars of GEDS.

Recognizing that countries may be at very different stages of development across these pillars – strong in one area but still emerging in another – the framework would be designed for flexibility. It would allow institutions to access tailored support, rather than follow a one-size-fits-all path. This modular approach would enable targeted progress, encourage peer learning and help align capacity-building efforts with countries' specific environmental priorities and institutional realities.

The framework would provide a flexible structure for countries and institutions to identify their current level, prioritize areas for improvement and access relevant resources. Key components could include modular training content, templates and toolkits aligned with each phase and pillar; curated guidance and case studies; a repository of open-source tools and platforms, including those suited to low-resource environments; and peer learning and mentorship models.

UNEP's role would focus on organizing, coordinating and selectively contributing to the development of tools and resources, in collaboration with regional and international partners. The aim would be to map, connect and adapt existing materials wherever possible, and to fill critical gaps where necessary. UNEP would work with partners to curate the core structure of the framework and would coordinate a shared platform for knowledge exchange. Implementation, contextualization and delivery of training would be led by Member States and by partners working through regional platforms and networks. Over time, the model would support a distributed, partner-led approach to capacity-building, embedded within broader digital development and environmental governance efforts.

Potential activities, timeline and resource needs

Timeline	Activities	Delivery	Est. cost
Framework development and mapping (3 years)	Co-develop the Environmental Data Capability Assessment Framework with pilot countries and partners	UNEP / partners	$700,000
	Map existing capacity-building tools, platforms and training programmes	UNEP	$400,000
	Identify priority gaps requiring UNEP coordination or support	UNEP	$200,000
	Begin design of online platform for knowledge-sharing and training tools, potentially as a pasrt of WESR	UNEP	$400,000
	Phase 1 subtotal		**$1.7 million**
Toolkit finalization and early rollout (3 years)	Finalize and publish the Assessment Framework and a self-assessment toolkit	UNEP	$500,000
	Soft launch of Phased Capacity-Development Model	UNEP / partners	$500,000
	Develop modular guidance and capacity resource maps	UNEP	$350,000
	Facilitate peer learning and uptake through regional platforms and networks	Partners	$600,000
	Begin development of targeted tools and training modules to address critical gaps	Partners	$400,000
	Phase 2 subtotal		**$2.35 million**
Integration and expansion (4 years)	Facilitate integration of the Assessment Framework and capacity model into national and regional initiatives	UNEP	$500,000
	Maintain and update tools, platform and materials based on feedback	UNEP / partners	$500,000
	Conduct evaluations and outcome reviews	Partners	$400,000
	Facilitate South–South collaboration and mainstreaming into governance systems	UNEP	$450,000
	Phase 3 subtotal		**$1.85 million**

Total indicative budget (2026–2035): $5.9 million

UNEP activities: $3.65 million

Member State and development partner activities: $2.25 million

Notes:

** In this table, "partners" refers to governments, regional organizations, development agencies, multilateral banks and other entities responsible for implementation.*

Activity-level costs include proportional administrative and coordination overheads (e.g. project management, reporting, travel and translation). These typically account for 10–15% of each phase's budget.

I.1.9 Summary of UNEP actions and indicative budgets

The table below summarizes the eight proposed actions UNEP could undertake to support implementation of the Global Environmental Data Strategy (GEDS). Each action is aligned to one or more priority intervention points outlined in Chapter 3 and is accompanied by an indicative 10-year budget estimate (2026–2035). These estimates reflect realistic costs for phased implementation, including expert coordination, tool development, pilot initiatives, capacity-building and regional support. Where future costs depend on design-phase outcomes (e.g. for Action 7), they are noted separately.

Action	UNEP activities	Country and development partner activities	Indicative budget (2026-2035)
1. Developing a guidance framework for national environmental data strategies	$1.55 million	$2.8 million	$4.35 million
2. Establishing a global mechanism for environmental data quality assurance	$2.45 million	$1.2 million	$3.65 million
3. Facilitating greater global alignment around essential variables and scientific standards	$6 million	$4.3 million	$10.3 million
4. Convening an Expert Group on Environmental Data Interoperability Standards	$2.8 million	$1.5 million	$4.3 million
5. Facilitating improvements to product sustainability disclosures	$7.3 million	$5.4 million	$12.7 million
6. Developing WESR as a federated platform that maintains data sovereignty	$3.8 million	$1.3 million	$5.1 million

7.	Establishing a Global Environmental Data Utility to ensure affordable access to essential environmental data	$3.3 million	$5.6 million	$8.9 million
8.	Creating a capability-assessment framework and capacity-development mode	$3.65 million	$2.25 million	$5.9 million
	Total indicative budget 2026-2031	**$30.85 million**	**$24.35 million**	**$55.2 million**

I.2 Implementation model and funding mechanism

Delivering on the GEDS vision will require sustained investment, coordinated implementation and broad-based cooperation across governments, international organizations, civil society, science and the private sector. As outlined in Section I.1, UNEP has identified eight actions aimed at building the tools, frameworks and enabling systems to support GEDS implementation by Member States and other partners over time.

This annex outlines a proposed model for coordinated delivery and financing of these actions. It is structured around three elements:

1. **an adaptive, phased implementation model**, with strategic guidance provided by a multi-stakeholder Steering Committee;
2. **a consortium-based funding mechanism**, designed to pool and align resources from Member States and other partners, and enabling catalytic investment in both UNEP-led activities and broader partner-led uptake.

As elaborated below, the proposed structure is intended to balance ambition with flexibility, enabling initial seed funding for foundational activities, while allowing priorities and resource flows to evolve through a collaborative governance process. Lessons from comparable international initiatives are outlined at the end of this section to illustrate the feasibility and advantages of the proposed model.

I.2.1 Implementation model: combining agile governance with stakeholder leadership

The proposed implementation model for UNEP's contributions under GEDS draws on lessons from other major UN-led frameworks, notably the Global Digital Compact (GDC). Like the GDC, the GEDS approach emphasizes phased delivery, adaptive governance and multi-stakeholder oversight to ensure legitimacy, responsiveness and long-term sustainability.

Each of the eight UNEP actions outlined in Section I.1 is structured around three broad implementation phases: foundations (three years), acceleration and upscaling (three years) and mainstreaming (four years). However, implementation is not expected to be strictly linear. Different workstreams may progress at different speeds. To accommodate this, UNEP proposes a modular and iterative model, underpinned by regular review, course correction, and stakeholder consultation. This mirrors the GDC's emphasis on agile, phase-based implementation that evolves in response to feedback and lessons learned.

A Steering Committee, similar in structure to the high-level GDC governance mechanism, would provide overall strategic direction, ensuring legitimacy and inclusiveness. The Committee would comprise representatives from Member States (both donors and implementing countries), international organizations, scientific and technical experts, civil society and the private sector. It would meet regularly to review progress, approve workplans, adjust priorities and advise on resource allocation.

To support implementation at a technical level, the Steering Committee could establish dedicated working groups, aligned to the eight actions (e.g. "Data quality", "Interoperability standards" and "Capacity development"), drawing on both consortium members and independent experts. These working groups would inform design, support piloting and help coordinate delivery across sectors and geographies. This echoes the GDC's use of thematic working groups to ensure coordinated action across complex areas of digital governance. UNEP would convene and support these groups as needed, focusing its own role on upstream coordination and tool development, rather than downstream delivery.

Together, this model offers a structured yet adaptable mechanism to manage implementation over a ten-year period. It ensures that UNEP's efforts can learn and evolve dynamically, alongside changes in technology, policy and partner demand, while maintaining transparency, inclusion and accountability.

I.2.2 Funding mechanism: a flexible, consortium-based approach

To support implementation of GEDS priorities, including both UNEP contributions and partner-led activities, a multi-stakeholder funding consortium is proposed. This body would serve as both a coordination and financing platform, enabling pooled investment, shared oversight and coherent delivery of GEDS priorities over a ten-year period. The model is designed to offer stability and strategic alignment while remaining agile and responsive to evolving needs.

Structure and governance

The proposed mechanism would take the form of a consortium governed by a formal agreement (such as a charter or memorandum of understanding), hosted either by UNEP or a neutral fiduciary partner such as the UN Multi-Partner Trust Fund Office or the World Bank. A pooled trust fund structure would enable contributors from governments, philanthropic organizations and the private sector to finance shared priorities in a transparent and coordinated way. This broadly follows the model of the World Bank's Global Data Facility.

The GEDS Steering Committee (described in Section I.2.1) would also guide the funding mechanism by setting strategic priorities, advising on resource allocation and maintaining high-level oversight. This dual function ensures alignment between implementation and financing, while minimizing duplication of governance structures. A high-level co-chairing model could help ensure balance and visibility, following the example of the Global Partnership for Sustainable Development Data. Voting rights could be tied to financial contributions, as in the Global Biodiversity Information Facility (GBIF), while non-contributing partners would participate as observers to ensure transparency and inclusiveness.

A secretariat, likely hosted by UNEP, would manage daily operations. It would coordinate workplans, disburse funds, oversee reporting, convene stakeholders and organize technical collaboration. To support delivery across the eight actions, the Steering Committee's working groups (see I.2.1) would also contribute technical input related to financing needs and priorities, drawing on both consortium members and external experts. This mirrors governance practices used by GEO and the Global Digital Compact, which rely on working groups to coordinate action and promote shared ownership.

Resource allocation and modalities

Funding would be deployed through a dual-track mechanism. On one hand, strategic grants would support the development of global public goods such as shared platforms, standards and reference tools. On the other, competitive calls or demand-driven proposals could support country-level piloting, regional partnerships and innovation. A technical panel could help review proposals to ensure that funding aligns with impact, readiness and GEDS priorities.

Resource allocation decisions would be made by the Steering Committee based on strategic priorities, implementation progress and emerging opportunities for collaboration or co-financing. In early years, investments would likely focus on foundational workstreams such as governance frameworks, data quality, interoperability and capacity development, with an emphasis on coordination, framework and tool development, and targeted piloting. In later phases, allocations would shift towards supporting wider uptake and integration, with Member States and other partners taking the lead. This approach draws on the demand-driven logic of the Global Data Facility, which allocates support based on country needs and potential for systemic improvement.

Accountability and transparency

To maintain trust, the consortium would operate under robust governance and reporting standards. Contributors would receive regular financial and performance updates aligned to international frameworks such as the International Aid Transparency Initiative. The fund would be subject to independent audits and periodic external evaluations. If hosted by UNEP, the consortium would follow established UN rules for extra-budgetary funding. A two-tier governance model could be considered, pairing a decision-making Council with a broader advisory forum to promote transparency and inclusion, as seen in GEO and GBIF.

Regular reporting to the UN Environment Assembly (UNEA) would ensure political visibility and reinforce the consortium's public mandate. Safeguards such as firewalls and open calls for funding would prevent conflicts of interest. The consortium's charter could set out clear rules to ensure that fund recipients are selected fairly and that oversight is rigorous.

Annexes II–V

UNEP has made initial investments and started various ad hoc multi-stakeholder consultation processes as core inputs to GEDS. These have generated valuable insights on user needs, existing platforms, data sources and standards. The following activities have been carried out to shape the framework for GEDS.

4.3 Preliminary analysis

- **UNEP Roadmap on Environment Statistics, Accounting and Analysis (2021).** This internal document aims to enhance environmental statistics and accounting to bolster the implementation of Sub-programmes on Nature, Pollution and Climate Action, aligning with the 2030 Agenda. It also focuses on developing innovative tools for statistical analysis, fulfilling UNEP's international obligations as a Custodian Agency for various SDGs and providing coordinated support on environmental information management to Member States and stakeholders.

- **Exploratory Analysis and Research for GEDS Conceptual Framework (2022–2023).** The document outlines a comprehensive framework for the development and implementation of a Global Environmental Data Strategy (GEDS), emphasizing the urgency of coordinated action, adaptive design principles and alignment with existing UNEP workstreams to effectively address environmental challenges. The recommendations for implementing GEDS encompass several key strategies: firstly, applying a Decentralized Autonomous Organization (DAO) mechanism to manage and access data consistently across the organization, ensuring transparency and efficiency. Secondly, emphasizing three pillars to transform GEDS into actionable objectives: cultivating enablers to drive change and innovation, nurturing capabilities to improve data technical aspects and support decision-making and enhancing adaptability through responsive analytics, prioritized use cases, data quality frameworks and cohesive data architecture. The document also discusses alignment with UNEP's current workstreams, particularly supporting environmental assessments and integrating environmental data through the WESR.

- **Inventory of UNEP data platforms and APIs (May 2023).** The inventory evaluated 41 environmental data platforms managed by UNEP, of which 28 APIs were developed in-house. The evaluation focused on the technical aspects of the platforms and the underlying data.

- **Preliminary mapping of Environmental Data Standards (July 2023).** Given the importance of seamless integration and analysis of data from diverse sources, UNEP undertook a preliminary mapping of existing environmental data standards. This exercise revealed the existence of national, regional and global environmental data standards, along with several thematic data standards. The most common type of standards are domain-specific and exist at different levels of implementation maturity. The existing thematic environmental data standards and their respective communities, custodians and conventions can serve as integral components in establishing specifications and requirements for the GEDS.

- **Survey of environmental data consumers and producers across UNEP (November 2023).** The findings, based on a survey of 75 respondents representing a diverse range of environmental experts and data scientists within UNEP, as well as a combination of data producers and consumers, highlight a range of challenges. These include inconsistent access to national environmental data, varied processes for validating external data and limited availability of relevant data for in-country engagements. Recommendations include prioritizing the development of metadata standards, ensuring data quality control, fostering interoperability via APIs, establishing an authoritative environmental data catalogue and implementing tailored capacity-building programmes focused on digital technologies.

- **External environmental data platforms inventory (2023–2025).** UNEP conducted an inventory of publicly available environmental data sources and platforms. As of February–March 2025, a review of over 650 environmental data platforms identified 464 platforms that directly align with the three Medium-Term Strategy (MTS) Pillars. The majority of these platforms contribute to multiple MTS pillars, with the strongest representation in climate change, biodiversity/wildife and water. However, many platforms primarily function as data repositories rather than offering advanced analytical interfaces. Of the platforms reviewed, 156 provide APIs, facilitating data access and integration, while 116 were recognized as best practices, characterized by comprehensive documentation, API availability, and robust analytical tools.

- **Development of use cases for WESR (2023 - ongoing).** UNEP has co-identified several priority use cases for the environmental data contained within the World Environment Situation Room based on consultations with end users. One of the use cases that will benefit greatly from GEDS is the development of environmental data dashboards to support UN Country Environment Dashboards (CED). It will provide UN Country Teams with a snapshot of the environmental performance of each country according to a suite of predefined environmental indicators. This involves providing the environmental data as well as the analytics and visualizations to help prioritize environmental actions and shape programming on the ground. The design of the environmental dashboards is based on a sustained discussion with UN Resident Coordinators and UN Country Teams over the past year on their data needs.

4.4 Preliminary stakeholder consultations

- **UNEP's contribution to the UN Round Table on Digital Public Goods (March 2020).** As a follow-up to the UN High-level Panel on Digital Cooperation, the UN Technology Envoy established a series of Round Tables, including one focusing on digital public goods. UNEP was requested to contribute a policy paper on environmental data entitled "**Error! Hyperlink reference not valid.**". The input was developed through a series of multi-stakeholder consultations with environmental data experts. The policy input provided a range of ideas to the Round Table including ways to operationalize the Global Environmental Data Strategy.

- **Coalition for Digital Environmental Sustainability (CODES) (June 2022).** UNEP together with UNDP, ITU, the International Science Council, Future Earth, the German Environment Agency and the Kenyan Ministry of Environment and Forestry act as co-champions for CODES – a platform for convening stakeholders from the environmental and digital transformation domains to agree on key priorities for digital environmental sustainability. A global environmental data strategy was identified as one of nine global priorities within the CODES Action Plan for a Sustainable Planet in the Digital Age – launched during the Stockholm+50 international conference. The CODES platform can be used to continue multi-stakeholder consultations across the membership of 1300 stakeholders.

- **Consultation with MEA secretariat data experts participating in the InforMEA initiative (June 2023).** An Extraordinary Working Group Meeting for InforMEA was held in-person on 20-22 June 2023 in Montreux, Switzerland on the topic of data and digital transformation. The meeting discussed a number of priority workstreams linked to data inter-operability ranging from semantic indexing to piloting UN document standards. It also discussed use cases for the applications of large language models and AI to national reporting to various conventions. Participants included data experts from the Convention on Biological Diversity, the Minamata Convention on Mercury, the Basel, Rotterdam and Stockholm Conventions, the International Treaty on Plant Genetic Resources, the Ramsar Convention on Wetlands, the Convention to Combat Desertification, the UN Framework Convention on Climate Change, the World Heritage Convention, the Multilateral Fund for the Implementation of the Montreal Protocol as well as participants from the IPCC and IPBES.

- **UN Science Policy Business Forum Consultations on GEDS** (September 2023). UNEP organized consultations on GEDS during the High Level Expert Group "Towards a Big Data Revolution for the Planet: Scoping an Integrated, Tech-Empowered Cross-Sectoral Approach to Data Optimization, Governance and Access to Meet Multilateral Environmental Goals " held from 11 - 13 September in Vienna. Over 150 participants joined the meeting including from academia, private sector, Member States, civil society, citizen science groups, as well as UN agencies. The meeting participants jointly identified a number of priority areas for GEDS including standards and governance processes linked to data inter-operability, quality, discoverability, accessibility and equity. The need for UNEP to perform a vetting and authentication function for the best available environmental datasets was also highlighted.

- **COP28 UNEP Digital Day Pavilion and Stakeholder Feedback** (December 2023). UNEP organized five sessions during COP 28, addressing themes ranging from national digital strategies to advanced AI applications. UNEP also participated in the data-focused sessions, organized by Estonia and the European Commission). Two panel discussions World Environment Situation Room: The Way Forward and Data For the Environment Alliance: DEAL for Informed Decisions, organized by the Ministry of Climate of Estonia, focused on how to reach the full potential of the World Environment Situation Room and attract a wide range of data, information and knowledge on the environment. The discussions emphasized the importance of data in informed decision-making for environmental sustainability, focusing on access and affordability. The session by the European Commission highlighted the need for merging environmental with development data, as well as capacity building. The Digital Day Pavilion also featured prototypes of various digital tools with opportunities for attendee feedback.

- **UNEA6 Digital Accelerator Lab and Stakeholder Feedback** (February 2024). UNEP organized an exhibition space called the Digital Accelerator Lab during UNEA 6. It provided a platform for various teams within UNEP to showcase their digital tools, solutions and prototypes while actively engaging with users to gather feedback. The Digital Transformation team curated and showcased a diverse array of tools, including 11 prototypes, 9 solutions and 14 reports and resources and TED-style talks. Through the exhibition, UNEP aimed to highlight the role of data in environmental action and policymaking, aligning with the objectives of the GEDS to enhance the effective environmental data management and use.

- **HLPF Consultation**. UNEP organized the first formal consultation on GEDS and WESR with Member States on the margins of the 2024 High-Level Political Forum on Sustainable Development (HLPF). The meeting gave an opportunity to the Member States to validate and provide feedback on current conceptual frameworks for GEDS and identify incentives, financing mechanisms and regulations to operationalize GEDS.

4.5 Member State and stakeholder consultations, 2024-2025

UNEP's consultations on GEDS aim to ensure diverse and detailed inputs with the engagement of Member States and a range of other stakeholders, including relevant UN agencies and other international bodies, the academic community, private sector entities, non-governmental organizations, including the major groups and stakeholders' organizations accredited to UNEP and other experts.

Most of the time of the **Member States consultations** will be spent in breakout sessions to best allow all delegates to contribute to identifying priorities, potential technical design approaches and areas where further support or multilateral action is needed to allow Member States to best benefit from the future GEDS.

Consultations with the major groups and other stakeholders such as UN agencies, the academic community and private sector organizations will be organized by UNEP, primarily via online meetings.

In addition, an online survey is available for more comprehensive, written input. The consultation sessions will all comprise a brief 10–15-minute presentation of the GEDS framework and current progress, followed by a detailed discussion of each pillar separately, focusing on the preliminary questions outlined below.

To ensure that the consultations are productive, participants are encouraged to prepare in advance by reflecting on the following proposed guiding questions.

Pillar 1: Quality and provenance

1.1 Frameworks and standards for defining and classifying data quality levels. What are the best-established standards for data quality, from your perspective?

1.2 What are the core issues affecting the quality and provenance of environmental data?

1.3 What mechanisms should we put in place to improve data quality? (e.g. create a global clearing house for data quality; implement regular data quality assessments)

1.4 What other organizations or experts are leaders in the field that you would recommend consulting? Please specify the key entities and individuals.

Pillar 2: Data governance

2.1 What key standards and best practices are influential in shaping current data governance models from your perspective?

2.2 What are the main challenges of current environmental data governance practices from your perspective?

2.3 What are the mechanisms we should put in place to improve data governance? (e.g. harmonized data governance frameworks; facilitating cross-border and cross-sector data sharing agreements)

2.4 What other organizations or experts in data governance would you recommend that we consult?

Pillar 3: Data interoperability

3.1 What key standards underpin data interoperability and how do they support or hinder data sharing across platforms?

3.2 Should the global community agree on a limited number of data interoperability standards? If so, how many?

3.3 What are the primary challenges to environmental data interoperability from your perspective?

3.4 What mechanisms do you think can enhance data interoperability?

3.5 Who are the main actors in your country facilitating the integration of global and thematic environmental data standards and what are some key initiatives in this area? Who else should we consult with?

Pillar 4: Data access and affordability

4.1 What are the key standards driving data access and affordability?

4.2 What obstacles currently hinder inclusive access to environmental data?

4.3 What mechanisms could help to overcome barriers to data access and affordability? Do we need an environmental data utility? How do we operationalize it?

4.4 Can you identify leading initiatives or projects that are making environmental data more accessible and affordable?

4.5 What other organizations or experts on data access and affordability would you recommend that we consult with?

Pillar 5: Capacity-building

5.1 What are the tech transfer needs to support the development of national environmental data sets?

5.2 What gaps in skills or knowledge are impeding effective environmental data governance from your perspective?

5.3 What mechanisms can facilitate capacity-building at a global scale?

5.4 Who in your opinion are exemplars for capacity-building in environmental data governance? Who would you recommend that we consult with?

4.6 Participation in the Member State and stakeholder consultations

From October to December 2024, UNEP organized five consultations with UN regional groups and major groups, involving 73 Member States. Smaller consultations engaged MEA secretariats, UN agencies, academic institutions, NGOs, private sector entities, standards bodies and philanthropic organizations. In total, more than 500 individuals participated. The organizations involved are listed below.

Major Groups consultation, 24 October 2024

- AMINI AI
- ASEAN Centre for Energy
- BASF
- Chemichemi Foundation
- Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
- Fauna and Flora International
- Impact Investment Exchange (IIX Global)
- International Organization for Standardization (ISO)
- MIT Office of Sustainability
- Pegasus Capital Advisors

African States consultation, 31 October 2024

- Algeria, Ministry of Foreign Affairs and the National Community Abroad
- Cameroon, Permanent Mission
- Centre for Environment and Development for the Arab Region and Europe (CEDARE)
- Democratic Republic of the Congo, Permanent Mission to UNEP
- Egypt, Mission to UNEP in Nairobi
- Eswatini, Environment Authority
- Ethiopia, Embassy in Kenya
- Ethiopia, Ministry of Planning and Development
- Global Green Growth Institute
- Grenada, Government
- Liberia, Environmental Protection Agency
- Madagascar, Ministry of Environment and Sustainable Development
- Morocco, Ministry of Energy Transition and Sustainable Development
- Republic of the Congo, Ministère de l'Environnement, du Développement Durable et du Bassin du Congo
- Senegal, embassy in Nairobi
- Tanzania, National Bureau of Statistics
- Tanzania, Vice President's Office
- Uganda, High Commission Nairobi
- United Nations Development Programme
- Zambia, High Commission Nairobi

Latin America and Caribbean States consultation, 5 November 2024

- Brazil, Ministry of Foreign Affairs
- Brazil, Ministry of the Environment and Climate Change
- Brazil, Permanent Representation to UNEP
- Costa Rica, Ministerio de Ambiente y Energía
- Dominican Republic, Ministerio de Medio Ambiente y Recursos Natuales
- El Salvador, Environment Ministry
- Guatemala, Ministerio de Ambiente y Recursos Naturales
- Mexico, Permanent Representation to UNEP
- Nicaragua, Ministerio del Ambiente y de los Recursos Naturales

- Trinidad and Tobago, Ministry of Planning and Development

Asia-Pacific States consultation, 7 November 2024

- Australia, Department of Climate Change, Energy, Environment and Water
- Bahrain, Supreme Council for Environment
- Centre for Environment and Development for the Arab Region & Europe (CEDARE)
- Japan, Embassy in Kenya
- Japan, Ministry of the Environment
- Ministry of Environment, Water and Agriculture, Saudi Arabia
- New Zealand, Ministry for the Environment
- Singapore, Ministry of Sustainability and the Environment
- Sri Lanka, Department of Census and Statistics
- UNEP-COBSEA

Eastern European States consultation, 26 November 2024 and 17 February 2025

- Azerbaijian, Ministry of ecology and natural resources
- Estonia, Ministry of Climate
- Estonia, Ministry of Foreign Affairs
- Permanent Mission of the Russian Federation to the International Organizations in Nairobi
- Poland, Ministry of Climate and Environment
- Poland, Statistics Poland
- Russian Federation, Federal Service for Supervision of Natural Resources
- Russian Federation, Federal State Budgetary Institution
- Russian Federation, Ministry of Natural Resources and Environment
- Russian Federation, Permanent Mission to UNEP
- Russian Federation, Russian Environmental Operator

Western Europe and Other States consultation, 3 December 2024 and 30 January 2025

- Belgium, Embassy in Nairobi
- Canada, Environment and Climate Change
- European Commission
- European Environment Agency
- European Union, Delegation to Kenya
- Finland, Finnish Environment Institute
- France, Ministry for Ecological Transition
- Germany, Environment Agency (UBA)
- Germany, Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)
- Israel, Central Bureau of Statistics
- Italy, National Institute for Environmental Protection and Research (ISPRA)
- Netherlands, Statistics Netherlands
- Norway, Environment Agency
- Saudi Arabia, National Center of Environmental Compliance
- Secretariat of the Convention on Wetlands
- Spain, Ministry for Ecological Transition and Demographic Challenge
- Switzerland, Federal Office for the Environment
- UK, Department for Environment, Food and Rural Affairs
- UK, Statistics Authority
- United States, Department of State

Pacific Island States Consultation, 10 December 2024

- Australia, Department of Climate Change, Energy, the Environment and Water
- Australia, University of Western Australia
- Cook Islands, National Environment Service
- Fiji, Ministry of Environment and Climate Change
- Secretariat of the Pacific regional Environment Programme (SPREP)
- Tonga, Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications
- Tuvalu, Department of Environment

Multilateral environmental agreement consultations, 2 and 17 December 2024

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Information and Communication Centre for the Barcelona Convention (INFO/RAC)
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
- Minamata Convention on Mercury
- Secretariat of the Basel, Rotterdam and Stockholm Conventions

United Nations consultations, 5 and 9 December 2024 and 21 and 23 January 2025

- Food and Agriculture Organization of the United Nations (FAO)
- United Nations Development Programme (UNDP)
- United Nations Economic Commission for Europe (UNECE)
- United Nations Office on Drugs and Crime (UNODC)
- United Nations World Data Forum (UNWDF)
- World Food Programme (WFP)
- World Bank Group (World Bank)
- World Trade Organization (WTO)

Additional stakeholders consulted

- ADET (Amis des Etrangers au Togo)
- Digital Impact Alliance
- HARC
- Iceburg Plus
- Innovea Development Foundation
- Internet Society
- Orange CSR Group
- Plant a Tree Foundation
- Redbutton
- Royal Bank of Canada
- SAP SE
- Université de Neuchâtel
- Vult Lab and Unstoppable Future Corporation

Additional Regional Consultations in June – July 2025 on the GEDS

UNEP's Chief Digital Office convened additional regional consultations (26 June – 1 July, hybrid format) with Member States from the five UN regions to review and strengthen the revised draft of the Global Environmental Data Strategy (GEDS). The consultations aimed to gather region-specific feedback on implementation priorities, budget estimates, and capacity needs. Over 50 participants—including government representatives and technical experts—shared insights on data quality, governance, interoperability, and equitable access. UNEP facilitated the sessions, presented key updates in the revised draft, and captured targeted feedback to refine the priority actions and research on the challenges and best practices in the environmental data ecosystem. These inclusive consultations ensured that the final strategy is better aligned with regional contexts, reinforcing the relevance of GEDS as a global coordination framework for environmental data.

Annex III Detailed analysis of challenges and responses identified during the GEDS consultations

Pillar I: Governance

Scope and vision

The data governance pillar encompasses the overarching framework of policies, institutions, practices, principles (at both national and international levels), which ensure that environmental data are accessible, interoperable, secure, good quality and contribute to effective policymaking and action. This includes:

- strategies, policies and institutions addressing the roles of different stakeholders at national and international scales and coordination of their work;
- ethical rules for collecting and using data;
- equitable data access and participation (e.g. for indigenous knowledge and groups);
- harmonization of legal and regulatory frameworks on data ownership and sharing;
- cybersecurity and data sovereignty;
- data stewardship – both managing the environmental burden of data storage and processing, and prioritization of certain data streams.

In the data governance context, achieving GEDS vision would imply that in 2035, global environmental data governance is coordinated and transparent, guaranteeing data sovereignty while enabling effective collaboration across borders and sectors. Governance principles and practices would be inclusive and equitable, empowering vulnerable communities and fostering secure, ethical and transparent data use. They would uphold data ownership rights, including for Indigenous Peoples and local communities, ensuring clarity over who controls, accesses and benefits from environmental data. They would also be responsive to the needs of all stakeholders to make data-driven decisions to support sustainable development. Critical indicators would be prioritized and environmental data would be routinely and verifiably integrated into policy and business strategies for a resilient future.

4.7 Key challenges and potential responses

Delivering a trusted, inclusive, accessible and interoperable global environmental data ecosystem requires coordinated action across multiple dimensions of governance. This chapter identifies five priority areas where targeted responses can drive transformative change: (1) guaranteeing data sovereignty and security; (2) strengthening national environmental data management; (3) coordinating global environmental data governance; (4) tackling inequities, power imbalances and ethical issues; and (5) ensuring effective data stewardship and managing data overload.

These areas were selected to reflect both foundational governance functions (e.g. sovereignty, institutions, coordination) and emerging governance challenges (e.g. AI ethics, private sector alignment). Together, they provide a comprehensive framework for strengthening how environmental data is governed, shared and used, both within countries and internationally.

Guaranteeing data sovereignty and security

Challenges

Guaranteeing data sovereignty: Governments have a right to ownership and control over their country's environmental data in order to protect national interests and security. Indigenous communities likewise have rights to control the collection, ownership and use of data about their lands, resources and cultures (Carroll et al., 2020). A global environmental data ecosystem that does not respects these rights will be unacceptable and unworkable. But balancing sovereignty with the need for collaboration and sharing will also be essential.

Risks of data colonialism and exploitation: Data colonialism arises where wealthy nations and corporations extract environmental data from less developed regions for commercial use without fair compensation or reciprocal benefits. Without proper governance structures, developing countries may be forced to rely on external actors for data access, further limiting their ability to independently monitor and respond to environmental challenges.

Cybersecurity and data integrity concerns: Weak cybersecurity protections, including the absence of encryption, authentication or secure backup protocols, leave datasets vulnerable to hacking, manipulation and unauthorized access, which undermines trust and discourages data sharing. In some cases, environmental data have been deliberately altered to obscure pollution, deforestation or climate impacts, undermining accountability and policy effectiveness. The lack of verification tools such as blockchain-based provenance tracking and digital signatures also raises questions about the authenticity of environmental datasets. These weaknesses create governance risks and leave environmental systems open to politically motivated tampering or systemic disruption.

Responses

A fair and viable global environmental data ecosystem can only be achieved if countries, Indigenous groups, vulnerable communities and other stakeholders are guaranteed data sovereignty and security. This means retaining control over issues such as what is collected, what is shared, what is accessible and to whom, and when information is deleted. Federated data governance models can support these goals by enabling cross-border collaboration while allowing data to remain under national control.

Strengthening national data sovereignty while enabling collaboration: All countries should be able to govern their own environmental data. At the national level that means establishing clear legal and institutional frameworks defining is published, what is shared, what is accessible to which actors and when information is deleted. Countries should take steps to build and maintain their own datasets and preserve their sovereignty, and they should be supported in these efforts.

At the international level, a functioning global environmental data ecosystem requires data sharing and integration. This points to the potential value in countries and regions adopting international agreements to facilitate data sharing by addressing issues of data sovereignty, jurisdictional conflicts and privacy protections. For example, an international agreement on environmental data sovereignty, drawing on frameworks such as the Aarhus Convention on environmental information access (UN, 1998), could set out principles balancing national and community sovereignty with global environmental needs, and offer clear guidance on data rights, governance responsibilities and ethical considerations.

Creating federated environmental data ecosystems: In practice, balancing national data sovereignty with global collaboration requires a federated governance model that enables countries to own and process their own data but make indicators and (where appropriate) datasets and methods available in central federated spaces. To deliver this, countries would need to develop the infrastructures to store, manage and selectively share their data. This includes adopting common data standards, APIs and sound classification methodologies to support structured and secure cross-border sharing. At the international level, central platforms are needed to bring together indicators and methodologies in ways that are accessible, transparent and respectful of national control. The UNEP World Environmental Situation Room could provide one such federated hub.

Respecting Indigenous data sovereignty: Data sovereignty should be understood not only as a state function but as a right held by all legitimate data owners and custodians, including Indigenous Peoples, and local communities. Governance efforts should prioritize collaborative engagement with Indigenous peoples in developing data that upholds their rights, knowledge systems and self-determined priorities.

At national and local levels, governments can embed Indigenous data sovereignty into legal and policy frameworks, while also recognizing and supporting local governance structures and customary protocols. To ensure that Indigenous communities retain control over data originating from their lands, resources and cultural practices, governments can enforce the principle of free, prior and informed consent (FPIC) and promote the co-development of context-specific guidelines that reflect local cultural protocols. This could include collaboratively developing data classification frameworks to guide which types of data can be shared, with whom and under what conditions, helping operationalize FPIC and cultural safeguards in practice. Co-designing models that offer communities reciprocal benefits for sharing data, such as technical support or financial compensation, can help mitigate data colonialism and exploitation. But the definition of "reciprocal benefits" needs to be agreed through participatory processes. Indigenous and local actors must have the means to engage in data-informed decision-making and determine how their data contributes to broader systems.

At international level, efforts should align with the UN Declaration of the Rights of Indigenous Peoples (UNGA, 2007) and the CARE Principles for Indigenous Data Governance (Carroll et al., 2020). International institutions can support Indigenous-led monitoring and invest in developing context-specific guidelines for research and data collection that respect local cultural protocols. A global framework could be developed to help identify and operationalize pathways for collective and reciprocal benefit, including mechanisms that link benefit-sharing to grant-making processes and data governance funding streams.

Box 0.1 The First Nations Information Governance Centre OCAP principles

In Canada, the First Nations Information Governance Centre has been developed the OCAP™ (ownership, control, access, possession) principles to guide how data and information is collected, protected, used or shared. These principles must be interpreted by each First Nation or community in a way that supports their core values and belief systems. In this way, the principles aim to preserve the sovereignty of First Nations and their community members (FNIGC, 2025).

Strengthening cybersecurity and ensuring data integrity: To build trust in environmental data platforms and uphold data sovereignty, governments must adopt robust cybersecurity measures and verification systems. At the national level, this includes implementing end-to-end encryption, secure APIs, multi-factor authentication and regular security audits. AI tools can also be leveraged to monitor access, detect anomalies and prevent unauthorized activities in real time. Internationally, coordinated action is needed to support secure, federated data sharing across jurisdictions. This includes adopting global cybersecurity frameworks such as ISO/IEC 27000 and IEC 62443, and developing protocols specific to environmental data ecosystems. Regulatory bodies like the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) can play a key role in defining and harmonizing these standards. Technology companies and research institutions should also contribute by integrating blockchain-based verification tools, digital signatures and transparent provenance tracking into environmental data infrastructures.

Strengthening national environmental data management

Challenges

Institutional silos and bureaucratic inertia: Institutional barriers between different sectors and levels of government pose significant challenges. Critical environmental data on issues such as pollution, land use and water quality are often collected by a diverse mixture of ministries and agencies. Too often, these data are not shared effectively because of a combination of bureaucratic resistance, unclear mandates and outdated data standards. Capacity building is often project-based and fragmented, rather than embedded in institutional processes, limiting sustained improvements in national data systems and the consistent application of quality control measures. In many cases, statistical offices lack clear data dissemination policies, making updates irregular and uncertain. Statistical offices frequently lack clear dissemination policies, sectoral actors may restrict access to data for legal or commercial reasons, and the absence of clear data-sharing policies often leads to ad hoc or inconsistent practices. Some datasets, such as those on recreational water quality, may be withheld due to perceived sensitivity or reputational risks. Meanwhile, institutional culture, competing incentives and low political prioritization can pose greater barriers than technical limitations.

Countries also face challenges in selecting environmental indicators that meet multiple reporting needs. Without agreed frameworks that align national priorities with global commitments, indicator development can become duplicative or inconsistent. A more coordinated approach to indicator selection could reduce reporting burdens, improve cross-sector data use, and support integrated environmental assessments.

Absence of strategic policy frameworks guiding and coordinating institutions: Many countries lack the strategic and legal frameworks that are the foundation for well-functioning and coordinated public institutions. National strategies or policy frameworks are essential to define the roles of different stakeholders; connect and harmonize the data policies and standards of different ministries and agencies with reference to global best practices; align with international reporting frameworks; and provide for the use of environmental data in public policy and decision-making processes (e.g. impact assessments, regulations, development plans).

Weak integration of private-sector and public-interest data needs: National environmental data strategies often prioritize official statistics and international reporting obligations but overlook the critical data needs and contributions of both businesses and consumers. Businesses increasingly rely on public environmental datasets, such as emissions factors, water stress indices and land-use maps, to support sustainability reporting, risk assessments, regulatory compliance and innovation. This dependence is only growing as regulations begin requiring more detailed product-level disclosures, which demand consistent, verifiable reference data to ensure credibility and compliance. At the same time, corporate disclosures and product-level data (e.g. on carbon footprints, recyclability, or pollution risks) are becoming key inputs to national inventories and environmental monitoring. Yet most national strategies do not effectively integrate these corporate data flows.

Similarly, national strategies seldom account for the rising demand from consumers and civil society for transparent, accessible information about the environmental impacts of products. Consumer protection agencies face challenges in enforcing safety and environmental claims without standardized, verifiable data. This undermines the rights of individuals to access environmental information, as enshrined in Principle 10 of the Rio Declaration and frameworks like the Aarhus Convention. Without policies that recognize both commercial interdependence and public entitlement, product-level data governance will remain fragmented and ineffective.

Responses

Developing national environmental data strategies: Strong national environmental data strategies policies and institutions are essential for ensuring that environmental data is systematically collected, managed and used in policymaking. They define roles and responsibilities, set data quality standards and address data privacy and security concerns. They also provide the foundation for actions to coordinate national data flows to reduce duplication of efforts and diverging standards. Governments can strengthen national data governance by adopting dedicated national environmental data strategies or embedding strong environmental data provisions within broader national data strategies. Such strategies should integrate internationally recognized principles such as FAIR (Findable, Accessible, Interoperable, Reusable), TRUST (Transparency, Responsibility, User focus, Sustainability, Technology), and CARE (Collective benefit, Authority to control, Responsibility, Ethics) to ensure data is managed ethically and effectively. Alignment with national and subnational digital transformation initiatives, such as e-government, open government and open science, can help embed environmental data governance within wider public policy frameworks and digital infrastructures.

International organizations, including UNEP and regional partners, can provide coordinated support through the development of guidance documents, templates and best practice examples that help countries apply these principles. They can offer technical assistance to countries during strategy development and implementation, especially to ensure interoperability with global data standards and alignment with international reporting obligations. Regional organizations can also help mainstream core data governance principles into regional policy frameworks. Peer learning networks and practitioner forums can share implementation experiences, foster collaboration, and build capacity across countries.

Embedding "openness" in national environmental data strategies: "Openness" is another important guiding principle, implying an emphasis on placing open data and open-source software at the core of environmental data strategies. Open data standards and open-source software are not necessarily cost-free, but they are developed through open participation and transparent, consultative processes.. Applying open data standards in strategy development promotes transparency as well as fostering innovation by making data accessible to a wider audience, including academia, civil society and the private sector. At the national level, governments can require the use of open licenses (e.g. Creative Commons, Open Government Licence) to ensure that datasets can be freely shared and reused across sectors. Environmental data strategies should adopt open, machine-readable formats and promote the use of open-source tools. Internationally, reference frameworks such as the International Open Data Charter and the World Bank's Open Government Data Toolkit provide guidance and tools for implementing openness. These can be disseminated through training, technical assistance and regional cooperation to support adoption and alignment.

Integrating businesses and consumers into national data planning: Governments can create more coherent national environmental data ecosystems by explicitly incorporating both business and consumer data needs into national environmental data strategies. This includes identifying key datasets of shared public–private value and promoting their open, timely release. Inclusive consultation processes can help define priority datasets not only for corporate reporting, but also for consumer protection, product transparency, and public accountability. Governments can establish structures, such as advisory panels or technical working groups, to ensure alignment between regulatory frameworks, corporate disclosure practices and national data infrastructures.

These mechanisms should also engage consumer protection agencies and civil society groups, ensuring that the public's right to environmental information is fully reflected in national strategies. As regulations increasingly require product-level sustainability information, strategies should also ensure that businesses have access to the public environmental reference data needed for credible, verifiable disclosures. Internationally, intergovernmental agreements processes can develop their indicator frameworks to align with relevant corporate metrics, enabling private-sector data to feed into national and global reporting. International bodies can support these efforts by developing common methodologies, metadata standards and sector-specific baseline parameters for corporate disclosures, facilitating more consistent and interoperable data across public and private actors.

Operationalizing data strategies through project-level planning: To help translate national data strategies into practice, governments can require large-scale public and private projects that generate environmental data to include machine-readable data management plans. These plans should detail data collection protocols, quality assurance processes, storage methods, interoperability mechanisms and compliance with national and international standards. Requiring plans in machine-readable formats enables automated compliance checks, improves metadata completeness and facilitates integration with national and global data infrastructures. This approach strengthens accountability and ensures that major projects contribute to coherent, standards-based environmental data systems.

Coordinating global environmental data governance

Challenges

Lack of unified data governance across environmental domains and scales: Addressing global environmental challenges like climate change, biodiversity loss and pollution requires cohesive data governance across governments, international organizations, academia, private sector and civil society. At present, global environmental data are scattered across platforms, sectors and countries at different scales of governance, leading to duplication of work and inefficiencies. Multiple organizations and initiatives operate in silos. Existing coordination efforts, such as the Global Earth Observation System of Systems (GEOSS, 2025), the Global Biodiversity Information Facility (GBIF, 2025) and the Ocean Data and Information System (ODIS, 2025), focus on specific domains but are not integrated into a broader global data governance structure. Similarly, networks such as the European Environment Information and Observation Network (Eionet, 2025) provide strong regional coordination but are not linked into a global system. Instead, countries and regions implement contrasting data-sharing policies and governance frameworks, creating barriers to international data exchange.

Weak cross-sectoral coordination: Despite being key producers and users of environmental data, private sector actors, academia and civil society are often excluded from formal data governance structures, meaning that environmental data policies do not always reflect multi-stakeholder needs and contributions. In addition, there is often limited alignment between environmental data governance and other sectors such as economic and social data, despite clear interdependencies. Limited cross-sector collaboration prevents open data initiatives from addressing broader challenges.

Limitations in MEA contributions to the global environmental data ecosystem: Multilateral environmental agreements (MEAs) play a central role in national environmental reporting, but their contributions to the broader global data ecosystem have historically been constrained by fragmentation and weak coordination, as well as a lack of tools to ensure full compliance with reporting requirements. Many MEAs developed independently, with differing reporting cycles, data definitions, taxonomic lists, formats and standards. Environmental data may also overlap with other domains (e.g. trade data for CITES).

Some of the variation in how MEAs handle reporting, such as the use of different formats or standards, is justified because agreements have distinct objectives, scopes and compliance mechanisms. For example, the Convention on Biological Diversity and the Basel Convention deal with very different subject matter and legal obligations, so some divergence is to be expected. Moreover, the data formats and standards for reporting under the MEAs are decided by the Parties to each agreement and aim to serve the specific purposes of that agreement.

However, not all differences are necessary or helpful. Some arise simply because of a lack of coordination between MEAs, for example the frequent absence of shared standards or joint planning, which leads to avoidable inconsistencies and duplication. As a result, Parties have often been required to submit overlapping information to multiple agreements, frequently in PDF or other formats that are difficult to access, compare or aggregate. This has increased reporting burdens and constrained the scope for MEA data to feed into a coherent global knowledge base to support decision-making and action. Parties sometimes exacerbate this problem by choosing not to share annual reports publicly.

Import progress has been achieved in the last decade to integrate reporting processes. The biodiversity-related conventions in particular have pioneered new tools and approaches to harmonize reporting. This includes developing online and modular reporting systems, aligning data standards across conventions, developing a common indicator framework and some steps towards synchronizing reporting cycles (Box 0.2). The Regional Seas Conventions and Action Plans have likewise initiated actions to harmonize reporting on ocean-related issues, helping to improve coherence across marine and coastal governance frameworks.

At a broader scale, the UN's InforMEA portal supports cross-MEA transparency by harvesting and linking national reports, legal texts and decisions from more than 20 multilateral environmental agreements. Through a unified metadata schema, shared ontologies, and interoperable APIs, it enables discoverability, comparability and machine-to-machine integration of environmental law and policy data. InforMEA's federated governance structure and capacity-building initiatives further contribute to coherent global environmental governance and more effective national implementation.

Box 0.2 Advances in harmonized reporting under the biodiversity-related MEAs

In the last decade, biodiversity-related MEAs have made strides in aligning and streamlining reporting systems. Key developments include:

- **Online reporting systems**: Ten biodiversity-related MEAs use the Online Reporting System (ORS) to support structured, digital submission of national reports, enabling harmonization of data formats and facilitates comparison across conventions. These systems support a modular approach to reporting, allowing Parties to reuse information across multiple reporting obligations, reduce duplication and align content with shared indicators and themes
- **Common indicators**: The CBD's Kunming-Montreal Global Biodiversity Framework includes a core set of indicators. Many of these are shared with or relevant to other MEAs (e.g. CITES, Ramsar, CMS), enabling more integrated monitoring and reducing duplication in national reporting.
- **Harmonized data standards**: Initiatives such as Group on Earth Observations – Biodiversity Observation Network (GEO BON) and the Biodiversity Indicators Partnership have supported greater alignment in definitions, metadata and measurement approaches across MEAs.
- **Synchronized reporting cycles**: Since 2023, the CBD and its Cartagena and Nagoya Protocols have adopted aligned reporting timelines to reduce duplication and facilitate joint planning and review processes.
- **Coordinating reporting across government**: UNEP's Data and Reporting Tool (DaRT) helps experts in different ministries improve the coordination and continuity of their reporting to the biodiversity conventions. It consolidates and organizes information submitted through the ORS, helping monitor and verify progress in national implementation; develop joint communications across conventions; conduct gap analysis of implementation actions; and update strategies and action plans.

Similar harmonization efforts are under way across other multilateral environmental agreements (MEAs). The development of shared data and indicators is being advanced through initiatives such as the Global Framework on Chemicals, the Belem Work Programme on Indicators for Climate Resilience and ongoing work under the Minamata Convention on Mercury. However, progress remains uneven across the MEA landscape. Several agreements have yet to adopt digital reporting platforms, common taxonomies or interoperable metadata standards. Even among frontrunners, persistent challenges remain, including how to strengthen country-level data collection, support the development of national monitoring systems, and build meaningful linkages between MEA reporting frameworks and data generated by non-state actors such as businesses and subnational authorities. Aligning MEA systems with broader environmental data flows is increasingly recognized as an important for improving transparency and implementation.

Responses

Creating a coherent system of global environmental data governance requires a clear understanding of the existing data landscape, how it is evolving and where there are opportunities for greater coordination. It also demands the development of flexible structures and tools that can guide and sustain incremental improvements in global environmental data governance – recognizing that such efforts much align with the provisions of each MEA, serve their respective objectives and be decided upon by their respective Parties.

Connecting and aligning existing initiatives and frameworks: There is substantial scope to increase the coherence of global environmental data governance by creating stronger links between existing platforms, streamlining overlapping tools, and aligning goals, indicators and methodologies across frameworks. This would mean building stronger connections between successful domain-specific initiatives such as GBIF (biodiversity data), ODIS (ocean data), and REACH (water security data); regional environmental networks like Eionet (Europe), SPREP (Pacific), and AMAP (Arctic monitoring and pollution data); and geospatial and Earth observation platforms such as GeoScience Australia, Digital Earth Africa and GEOSS. Strengthening links between these initiatives and with data systems in other sectors, including health, energy and finance, will be essential to create a more integrated global environmental data ecosystem. There is also scope to expand ongoing efforts (e.g. by the InforMEA initiative) to map overlapping and complementary targets and indicators across MEA strategic plans, which can provide a foundation for more interoperable reporting and monitoring. Shared indicator criteria, such as open access, transparent methodologies and clear custodianship, can further support this alignment, helping to ensure that indicators are robust, interoperable and useful across policy processes.

Supporting indicator harmonization and infrastructure to strengthen national MEA reporting: While recognizing the legal autonomy of MEAs, there is value in continuing efforts to align indicator definitions, synchronize reporting cycles and develop common templates for digital reporting. Interoperability can be promoted by creating tools to structure and share data from diverse sources in ways that support national reporting. In the biodiversity domain, for example, partners such as GEO BON, the GEO Atlas, FAO, UNSD and IUCN generate geospatial datasets that underpin key indicators. Greater coordination among these actors and clearer processes for making their data interoperable and accessible through platforms such as UNEP's World Environment Situation Room (WESR), would strengthen the foundations for integrated reporting. In parallel, global platforms can support countries by offering tools and guidance to help generate the data products required for effective monitoring and decision-making.

Linking corporate disclosures to global indicator frameworks: Environmental data governance needs to reflect the roles of a wider range of contributors, including private companies, scientific networks and civil society organizations. While corporate sustainability disclosures and MEA reporting serve distinct purposes and MEA reporting remains a Party-based obligation, there is growing recognition of the benefits of structuring corporate data in ways that support broader indicator frameworks. Common metrics, such as ecosystem extent, can serve both MEA reporting and private-sector frameworks like the Taskforce on Nature-related Financial Disclosures (TNFD) and the Science Based Targets Network (SBTN). Moreover, initiatives such as the UNEP Finance Initiative offer guidance to help align corporate disclosures with global environmental goals. Similarly, the Global Framework for Digital Product Information Systems (DPIS) supports this agenda by helping countries to integrate business use cases for sustainability product data into broader national data strategies. Cross-sectoral working groups, shared indicator platforms and interoperable metadata standards can further strengthen these links, not by altering MEA obligations but by enabling business-generated data to complement national assessments and global monitoring systems, where appropriate.

Investing in national monitoring capacity and data infrastructure: Sustained investment is needed to build national capacity to collect, manage and report environmental data. Public investments are needed to develop the core datasets required by international frameworks, improve data quality and enhance the ability of institutions to generate and use geospatial and statistical information. At the international level, investments in these systems can be mobilized through partnerships with development agencies, environmental funds and scientific networks. Global actors can provide technical assistance, facilitate peer learning, and fund infrastructure, tools and training to support national implementation. Additional value can be created by engaging with actors such as citizen science platforms, Earth observation programmes and biodiversity data networks to help fill critical data gaps. Improving national capacity is essential not only for reporting compliance but also for enabling evidence-based planning, monitoring and implementation at national and subnational levels. Equally important is strengthening national coordination mechanisms, for example by improving information flows between MEA focal points, harmonizing institutional roles across ministries and establishing shared data management protocols. Without these, investments in data systems may fail to deliver integrated, coherent reporting and decision-making.

Tackling inequities, power imbalances and ethical issues

Challenges

Unequal participation: Global environmental data governance often reinforces existing inequalities, particularly for Indigenous groups and other marginalized communities, and for developing countries. Many lack the financial, technical and institutional capacity to participate fully in decisions about data governance or to access critical environmental data. While Indigenous knowledge plays a crucial role in biodiversity and ecosystem management, it is frequently overlooked, undervalued or exploited (Turner et al., 2022). In some cases, Indigenous communities are consulted but not given a meaningful role in decision-making processes, limiting their ability to shape policies that impact their lands and resources.

Dominance of high-income regions in environmental data and research: Environmental research, policy frameworks and datasets are often dominated by developed nations, leading to a skew towards their perspectives. The IPCC process, for example, has historically relied on peer-reviewed literature from developed countries, making it difficult for developing nations' experiences and research to be adequately represented in climate adaptation and environmental vulnerability assessments (Tandon, 2021). Efforts have been made to address this imbalance by incorporating government studies and non-traditional research sources. Yet significant disparities remain.

Unfair and selective data sharing practices: The lack of fair and transparent data-sharing mechanisms further exacerbates inequalities. Licensing fees for software, complex formats and limited infrastructure create barriers for low-income countries and marginalized communities. Data sharing at the international level will be essential to scale environment and climate action. However, without transparent and fair rules for data sharing there may be an increase in hoarding and selective sharing of data or even manipulation. This could reinforce existing imbalances, resulting in poor decision-making and reduced accountability, particularly for countries and communities that lack independent data sources.

Ethical challenges of artificial intelligence: The growing use of AI raises concerns in relation to issues such as transparency, misuse of data, a lack of inclusivity in the development of AI systems, bias and accountability gaps when problems arise. AI models are only and good as the data they have been trained on. If these data already contains power imbalances and inequities then it will be perpetuated in the AI models and results. This includes well-documented gender biases, which can skew both representation and outcomes in AI-supported decision-making. It is vital that this is acknowledged and addressed to prevent AI reinforcing existing imbalances and inequities. Moreover, strong ethical frameworks and oversight are needed to ensure AI is used responsibly and equitably in environmental decision-making.

Responses

Addressing the inequities in global environmental data governance requires greater inclusion of Indigenous and developing country perspectives, fairer data-sharing rules and stronger mechanisms to prevent data exploitation. As noted in Section 4.3.2, the Global Indigenous Data Alliance's CARE principle provide an important foundation for developing data strategies and policies at all levels of governance.

Enabling inclusive participation in environmental data governance: Governance mechanisms at local, national and international levels can be introduced to help ensure that Indigenous peoples, marginalized communities and developing countries are able to participate actively in decision-making processes, for example in relation to biodiversity data. Countries could setting up advisory councils or institutional mechanisms that recognize and integrate Indigenous knowledge alongside conventional scientific data, and build capacity in data collection, management and analysis to enable marginalized groups to participate fully in governance and decision-making. National governments can support local and subnational participation by funding inclusive consultation processes and embedding participatory governance in law and policy.

At the international level, governance bodies can institutionalize participation from Indigenous groups in decision-making processes. Capacity-building efforts and multi-stakeholder dialogues can empower NGOs, Indigenous groups and researchers from developing regions to contribute directly to data governance policies and frameworks, define data priorities and contribute directly to the generation of environmental knowledge. Global funding mechanisms can further support research focused on under-represented environments and species that are valued by Indigenous and local communities.

Supporting NGOs to empower marginalized communities: NGOs often play a crucial role in data collection and as bridges between marginalized communities and global environmental data networks. They help interpret and apply data locally, ensuring regionally relevant insights inform decision-making. Their work addresses the 'westernization of data', where datasets are often produced in and for wealthier nations. Despite this role, many NGOs struggle to access global environmental datasets, reinforcing inequities in data governance. Governments can address this by partnering with and funding NGOs to facilitate grassroots engagement in environmental monitoring and governance.

Internationally, efforts could focus on expanding open-data agreements, supporting decentralized data-sharing platforms and ensuring that NGOs have equitable access to global environmental datasets, including on UNEP platforms such as WESR. By avoiding overly restrictive funding criteria, international institutions can also enable NGOs to co-create localized projects with Indigenous Peoples and local communities, embedding data justice in both process and outcomes.

Mainstreaming gender in environmental data strategies: At the national level, statistics offices can promote equity by fully implementing Decision 51/115(b) of the United Nations Statistical Commission (UNSC, 2020), which focuses on mainstreaming gender across all areas of work. This includes establishing gender-sensitive indicators, disaggregating environmental data by sex, and aligning environmental statistics with broader gender equality objectives. At the international level, governments and UN agencies can support UNSC and the Inter-Agency and Expert Group on Gender Statistics in developing guidelines and tools to support the integration of a gender perspective into environmental statistics.

Prioritizing open data and open science principles: Supporting open data and open science means allowing researchers, policymakers and the public to access and contribute to environmental data. National governments can provide support by investing in public data literacy programmes and ensuring that environmental information is accessible and understandable in ways that are relevant to local contexts. At all levels of governance, communicating environmental information effectively can empower citizens to engage in evidence-based decision-making and advocacy efforts.

Diversifying environmental research frameworks and forums: At the national level, governments and research institutions can promote inclusion by supporting research that draws on non-traditional sources and locally generated data, especially from Indigenous Peoples and local communities. National research funding mechanisms can prioritize collaborations with underrepresented groups and ensure that findings feed into domestic policy and reporting systems. At the international level, global environmental assessments and science-policy platforms can broaden the types of evidence they recognize, embedding equity and inclusivity principles more effectively. There is also scope to increase support for initiatives that fund research led by or in collaboration with researchers from developing nations.

Addressing ethical challenges of AI in environmental data governance: As AI becomes increasingly prominent in global environmental data governance, it will be important to increase transparency, inclusivity and accountability. At the national level, governments can promote transparency by promoting open-source AI models and third-party audits, and by implementing data lineage tracking to make AI-driven decisions explainable and verifiable. Efforts should also focus on ensuring that AI models are trained on diverse datasets, including gender-disaggregated data, Indigenous knowledge and data from developing country perspectives. This is essential to reduce bias and prevent the replication of existing inequalities, such as gender, racial or geographic disparities, which are embedded in historical datasets. Ethical oversight bodies or advisory mechanisms can help monitor AI deployment in environmental policy and ensure alignment with principles of data justice and public interest.

At the international level, developing shared ethical frameworks for AI use in environmental data governance is critical. These frameworks should explicitly address issues of inclusivity, transparency, and equity, including requirements to identify and mitigate gender bias in AI systems. International cooperation can help establish standards for responsible design and deployment, create mechanisms for redress and accountability, and ensure that AI tools remain accessible to all regions. That particularly includes those at risk of being further marginalized by digital divides. Global institutions can also play a role in convening multi-stakeholder dialogue and supporting capacity-building to promote fair and ethical AI integration into environmental decision-making.

Actions to promote equitable and transparent sharing of environmental data are also essential. These are addressed in Pillar IV on access and affordability.

Ensuring effective data stewardship and managing data overload

Challenges

High resource demands collecting and managing data: The exponential growth of environmental data, coupled with the expanding role of AI has led to rising energy demands for data processing and storage, and a substantial environmental footprint. Much data is collected without a clear conception of its purpose. Managing and maintaining vast datasets is labour and resource intensive, while the sheer volume and complexity of environmental data makes it hard to integrate. Getting all the stakeholders to agree on priority data and common standards is difficult, suggesting that this is as much a social challenge as a technical challenge.

Inefficiencies in data infrastructure: Current data infrastructures and workflows are costly and inefficient, placing heavy burdens on data providers for storage, hosting and processing – particularly for spatial data. As demand for environmental data grows, bottlenecks in accessibility and usability will become an increasing challenge.

Proliferation of indicators and reporting requirements: The sheer volume of environmental indicators and reporting obligations is overwhelming. Even developed countries struggle to comply with their reporting obligations, while many developing nations find full participation impossible. The proliferation of data hinders decision-making, as governments face difficulties mobilizing resources to collect new data and develop additional indicators. To improve effectiveness, there is a need to prioritize and streamline reporting requirements, ensuring that environmental data remains actionable and impactful rather than an administrative burden.

Responses

Managing the proliferation of environmental data and associated resource demands and environmental impacts requires a strategic response, combining identification of priority data flows, while building sustainable, interoperable data infrastructure.

Identifying and standardizing priority datasets and variables can help streamline data collection and optimize resource allocation by focusing efforts on essential environmental datasets. This approach reduces the burden on governments and stakeholders while ensuring that critical environmental variables are consistently monitored and updated globally. At the national level, governments and statistical or geospatial agencies can work to align data collection with these shared priorities, while developing policies and systems that enable the sustainable production, management and sharing of high-value datasets. This includes cataloguing national datasets, improving metadata practices, and ensuring data quality and interoperability within domestic systems.

At the international level, agreeing on a core set of foundational datasets that all countries commit to share could create a baseline for global cooperation, helping to balance national data sovereignty with the need for integrated global environmental data. The UN-GGIM's Integrated Geospatial Information Framework (IGIF), which outlines foundational geospatial datasets, offers a useful model for this approach. The Committee on Earth Observation Satellites (CEOS) Essential Variables Framework identifies globally relevant, observation-linked variables to guide investment and standardization in Earth observation systems. Building on these activities, UNEP could work with scientific bodies to identify a set of high-value environmental models and datasets, ensuring scientific rigour and usability. Developing a certification of 'approved' data sources could further encourage the use of trusted, high-quality datasets for reporting.

Prioritization efforts must remain flexible to avoid stifling innovation, allowing for the integration of emerging technologies, novel monitoring methods and region-specific data needs. The challenge lies in balancing global consistency with local adaptability to foster both standardization and innovation in environmental data governance. Experience with developing and operationalizing a set of Essential Biodiversity Variables to support global biodiversity efforts highlights both the initiative's substantial potential and practical difficulties with implementation (Kissling et al., 2018).

Building sustainable, efficient and interoperable data infrastructure is essential to reduce environmental impacts. At the national level, governments can implement policies to promote energy-efficient, low-carbon data storage solutions, including using renewable energy in environmental data centers – as outlined in the forthcoming U4E Sustainable Procurement Guidelines for Data Centres and Computer Servers (UNEP, 2025). They can also invest in modular data systems, improve metadata practices and develop integrated platforms that support coordination across agencies and reduce duplication of data.

At the international level, coordination is needed to develop federated environmental data systems that enable countries to retain control over their data while facilitating access and integration. Global actors can support this by promoting common interoperability frameworks, harmonizing data standards and cataloguing metadata to facilitate discovery and reduce redundant data collection. As set out in Pillar III, such measures are critical to ensure that global environmental data systems are scalable, connected and fit for purpose in the face of growing demand.

4.8 Summary of key responses

Table 0.1 summarizes the key actions proposed under each of the five thematic areas addressed under Pillar I, spanning both national and international levels.

Table 0.1 Summary of key actions to enhance data governance

Section	Key actions
1.2.1 Guaranteeing data sovereignty and security	• Establish national legal frameworks to govern data access, sharing, deletion and privacy. • Develop federated governance models that enable collaboration while respecting national control. • Uphold Indigenous data sovereignty through co-designed governance protocols, Free, Prior and Informed Consent (FPIC) and reciprocal benefit-sharing. • Promote cybersecurity by adopting secure digital infrastructures and international security standards. • Develop and implement national data classification schemes to clearly distinguish between public, restricted and confidential environmental data, enabling secure and appropriate data sharing. • Support the implementation of data enclaves and/or Data as a Service (DaaS) architectures, to allow analytics to be performed on obfuscated and localized data stores.
1.2.2 Strengthening national environmental data management	• Develop national environmental data strategies or integrate environmental provisions into broader national data policies, embedding the FAIR (Findable, Accessible, Interoperable, Reusable), TRUST (Transparency, Responsibility, User focus, Sustainability and Technology), CARE (Collective benefit, Authority to control, Responsibility and Ethics) and openness principles. • Further promote openness by adopting open licenses, machine-readable and machine-actionable formats and open-source tools. • Integrate business and consumer needs into national strategies by identifying priority datasets of shared value and establishing coordination mechanisms that engage relevant stakeholders. • Operationalize national data strategies by requiring relevant large-scale projects to develop machine-readable and machine-actionable data management plans.

	• Incorporate citizen science into national environmental data strategies, recognizing its value in gap-filling, cost-effectiveness and community engagement.
1.2.3 Coordinating global environmental data governance	• Connect and align domain-specific, regional and geospatial platforms by mapping interdependencies and developing shared indicators. • Support further harmonization of MEA reporting by aligning indicator definitions, technical specifications, reporting cycles and geospatial data structures, and making data accessible through interoperable platforms. • Support alignment between corporate disclosures and global indicator frameworks by promoting interoperable standards and shared platforms. • Invest in national monitoring systems and data infrastructures, leveraging global funding and technical assistance to enhance country-level capabilities.
1.2.4 Tackling inequities, power imbalances and ethical issues	• Ensure inclusive participation in governance by engaging Indigenous and marginalized voices at all levels and investing in capacity-building. • Empower non-governmental organizations (NGOs) as data intermediaries and ensure they have equitable access to environmental data platforms. • Mainstream gender through sex-disaggregated data, gender-sensitive indicators and targeted support for inclusive environmental statistics. • Promote open data and open science to strengthen public engagement and evidence-based decision-making. • Clarify and uphold data ownership through co-developed frameworks that ensure transparency over access, control and benefit-sharing. • Ensure AI use is transparent, inclusive and ethical, with appropriate training data and shared frameworks to prevent bias and exclusion, and supported by practical guidance to align with UN principles on responsible AI.
1.2.5 Ensuring effective data stewardship and managing data overload	• Identify and prioritize high-value datasets and variables to streamline reporting and reduce redundancy. • Promote efficient, low-carbon data infrastructure and federated systems that support interoperability while managing environmental impact.

4.9 Overview of best practices in Pillar I

Example	Section

The First Nations Information Governance Centre's OCAP principles preserve the data sovereignty of First Nations.	1.2.1 Guaranteeing data sovereignty and security
The Global Indigenous Data Alliance's CARE principles build on the FAIR principles with a particular focus on Indigenous sovereignty	1.2.1 Guaranteeing data sovereignty and security
WB's Open Government Data Toolkit and the International Open Data Charter promote open data as a guiding principle for environmental strategies.	1.2.2 Strengthening national environmental data management
Open Up Guide for Climate Action by Open Data Charter helps establish clarity and direction for governments looking to improve their climate-related open data publication.	1.2.2 Strengthening national environmental data management
InforMEA supports data governance by implementing APIs and metadata standards, harvesting and linking national reports, legal texts and decisions from more than MEAs.	1.2.3 Coordinating global environmental data frameworks
The ORS is used by 10 biodiversity-related MEAs to support digital submission of national reports, enabling harmonization of data formats and facilitates comparison across conventions	1.2.3 Coordinating global environmental data frameworks
The GBF defines a core set of biodiversity indicators. Many are shared with or relevant to other MEAs, enabling more integrated monitoring and reducing duplication in national reporting.	1.2.3 Coordinating global environmental data frameworks
GEO BON and the Biodiversity Indicators Partnership have support alignment of definitions, metadata and measurement approaches across MEAs.	1.2.3 Coordinating global environmental data frameworks
UNEP Finance Initiative supports alignment of corporate data with global environmental objectives.	1.2.3 Coordinating global environmental data frameworks
Global Framework for Digital Product Information Systems (DPIS) helps countries integrate business use cases for sustainability product data into broader national data strategies.	1.2.5 Data stewardship and managing data overload
U4E Sustainable Procurement Guidelines for Data Centres and Computer Servers	1.2.5 Data stewardship and managing data overload
UN-GGIM's IGIF and the CEOS Essential Variables Framework offer models for prioritizing key datasets to guide investment and standardization of data.	1.2.5 Data stewardship and managing data overload

5 Pillar II: Quality and provenance

5.1 Scope and vision

The data quality and provenance pillar addresses the tools and approaches needed to ensure that the global environmental data ecosystem is producing sufficient good quality data to meet the needs of governments, businesses and other stakeholders. As such, this pillar takes a broad view of data quality, encompassing not only technical characteristics such as accuracy and consistency, but also availability and relevance to user needs. It includes:

- availability and completeness of datasets and metadata;
- standardization of collection and processing protocols;
- transparency and bias issues;
- quality assurance and quality control;
- data lineage and traceability systems;
- trust and credibility;
- alignment of data with the needs for decision-making and integrated assessment.

The topic of data quality and provenance is clearly closely tied to issues of accessibility, interoperability and capacity-building, which are further elaborated in Pillars III, IV and V.

In the data quality and provenance context, achieving GEDS vision would imply that in 2035, we have a global environmental data ecosystem that delivers data that are accurate, consistent and fit for purpose, based on robust and transparent processes and validation protocols, and comprehensive metadata. Good quality data empower decision-makers with trustworthy and explainable insights, bridging the gap between global and local data needs. Collectively, quality control, quality assurance and complete provenance tracking will create a data ecosystem that fosters confidence in environmental datasets, enabling informed, equitable and sustainable actions worldwide.

5.2 Key challenges and potential responses

Addressing gaps, inaccuracy and biases in environmental datasets

Challenges

Gaps, inaccuracy and biases in environmental data weaken research and policy. Many regions lack consistent monitoring, while data biases favour developed regions and well documented species. Local data gaps constrain policy interventions, while citizen science remains underutilized due to quality concerns.

Missing or incomplete environmental data: In many parts of the world, monitoring of environmental variables is limited or absent, making it impossible to track long-term trends, inform decision-making and assess progress towards global or national targets. In some instances, datasets exist but are only collected periodically or in an ad hoc manner, leaving temporal gaps that hinder analysis of environmental changes. The problem is particularly acute in ecosystem monitoring, where essential data on species populations, habitat conditions and ecosystem health are often insufficient or entirely missing. Similarly, data on chemical pollution and emerging environmental risks remain fragmented, meaning that even when certain pollutants are identified, their long-term environmental impacts are poorly understood. Many datasets are not updated frequently enough to reflect real-time or near-term environmental changes, limiting timely responses to environmental crises. In some instances, datasets exist but are only collected periodically or in an ad hoc manner due to inconsistent funding.

Biases in existing datasets: Even when environmental data are available, biases and inconsistencies reduce reliability. Certain ecosystems, species and pollutants are well-documented, while others are under-represented, leading to distortions in environmental assessments. In biodiversity monitoring, for example, mammals, birds and temperate regions are well tracked, while amphibians, insects and deep-sea species lack sufficient data (Titley et al., 2017). Geographic biases further compound problems. Environmental datasets are heavily concentrated in the developed regions (Trimble and Van Aarde, 2012). As a result, global environmental models and AI-driven tools are often trained on incomplete data, reducing their accuracy when applied to diverse ecosystems and weakening their usefulness. It can also have economic and environmental costs, as the results cannot be used effectively.

Lack of local and hyper-local data: National and global datasets often fail to capture city-level, community-level and household-level environmental changes, limiting their usefulness for local decision-making, for example in relation to ecosystem service provision. Local and hyper-local data are often an important counterpart to global-level indicators, which may not capture the realities in particular local contexts. The absence of local environmental data hinders effective city and community-level environmental planning and is also an important resource for training AI models, although such data can be sensitive and personal in nature, raising issues about individual consent to their use.

Need to validate data sources: The increasing reliance on low-cost sensors for environmental monitoring raises concerns about data accuracy, calibration and standardization. These sensors provide valuable insights and their low cost enables better spatial coverage, which makes interpolation possible. However, their data often lack the precision of reference-grade instruments, necessitating rigorous validation protocols. Additionally, satellite-derived environmental data must be systematically ground-checked to ensure accuracy, particularly for applications such as air pollution modeling, wildfire tracking and climate change projections.

Gaps in ESG reporting at entity and product levels: ESG reporting is becoming an increasingly important source of environmental data, particularly for informing sustainable finance, procurement, and investment decisions. However, the coverage, consistency, and granularity of ESG disclosures remain highly uneven, limiting their utility for robust environmental analysis. At the level of corporate reporting, most ESG frameworks, including the European Sustainability Reporting Standards (ESRS) and the Task Force on Climate-Related Financial Disclosures (TCFD), apply only to large or publicly listed firms, primarily in developed markets. As a result, high-emitting small- and medium-sized enterprises (SMEs), informal actors, and suppliers in low-income countries are typically excluded from structured reporting. Even where firms disclose environmental data, reporting is often based on broad entity-level summaries, with limited disaggregation by geography, production facility, or product line. This hinders efforts to trace environmental impacts through supply chains or to link reported data with local environmental conditions. At the product level, environmental data such as lifecycle impacts or carbon footprints are typically disclosed voluntarily and are highly inconsistent across sectors and regions. This results in patchy and often non-comparable datasets that cannot reliably inform cross-product or cross-market assessments.

The usefulness of ESG disclosures increasingly depends on the availability of transparent, high-quality environmental data that companies can draw on to support credible reporting. Businesses are seeking more granular, validated datasets – particularly geolocated data relevant to sectors such as extractives, energy and agriculture – to underpin risk assessments, site-level reporting and supply chain transparency. There is also growing interest in nature-related financial disclosures. However, progress is limited by gaps and inconsistencies in core environmental datasets, which are often incomplete or not designed for corporate reporting needs. To improve comparability and efficiency, many companies are turning to centralized or federated data infrastructures that consolidate relevant datasets and support standardized reporting.

Challenges in employing citizen science: Citizen science can leverage smartphones and community-driven participation to generate vast, granular datasets. Among the substantial potential benefits of citizen science, it potentially offers a valuable tool for improving the completeness and quality of data from other sources. However, the quality of citizen science data is variable and can be difficult to control. For instance, some citizen science air quality monitoring may use low-cost sensors that do not follow standardized calibration methods. As a result many local and community-led environmental monitoring initiatives generate valuable datasets that lack integration with global environmental databases, partly because of perceptions that they are of insufficient quality. Very little citizen science data is used to inform decision-making or incorporated into official national monitoring and reporting on different environmental goals, implying limited impact on decision-making.

Responses

Ensuring high quality and complete environmental datasets depends on diverse action to establish robust data protocols and QA/QC processes (Section 3.2.2) and consistent metadata (Section 3.2.3) and, above all, efforts to build the broad range of capacities needed to collect, process and disseminate data (Chapter 6). However, a variety of other interventions can help improve the quality and coverage of existing datasets, including AI-driven data validation, triangulation techniques and the integration of citizen science.

Implementing routine data profiling and audit mechanisms: Data profiling and auditing can enhance environmental data quality by systematically identifying inconsistencies, biases and gaps. At the national level, regular profiling can detect missing values, anomalies and format inconsistencies, ensuring that they adhere to established QA/QC protocols. Periodic audits, conducted by independent national data governance bodies or automated AI-driven systems, can verify compliance with data standards, assess representativeness across geographic and demographic dimensions, and evaluate the reliability of data sources. At the international level, global organizations can promote structured bias detection methods, such as those developed by UN Office on Drugs and Crime, to address underreporting and inconsistencies in national statistics. Adapting such tools for use in environmental data systems could help improve comparability and correct for systemic distortions

Leveraging AI to enhance data quality, accuracy and integration: AI has the potential to revolutionize environmental data governance by automating quality control and anomaly detection, identifying real-time errors and enable predictive modeling. At both national and international levels, machine learning algorithms can be used to detect inconsistencies in large datasets, such as satellite imagery, biodiversity records or emissions data. AI-powered computer vision can also verify land cover changes, pollution patterns and deforestation rates with greater precision. AI can impute missing values, reconstruct incomplete time-series data and generate synthetic datasets for poorly surveyed regions. Governments and international institutions can also use AI to harmonize and integrate environmental datasets from different sources, such as satellites, ground-based monitors and IoT sensors (Box 5.1). Natural language processing techniques offer further potential to expand environmental literature reviews, including non-English sources, ensuring that scientific contributions from a broader array of sources are recognized in global environmental modelling and forecasting. UNEP and its partners could facilitate and promote ethical and transparent use of AI to improve data quality by developing relevant guidance materials.

Box 5.1 AI-driven environmental monitoring in Estonia and France

Estonia has moved rapidly to promote the uptake of AI in recent years and its use to address societal challenges, such as climate change. Machine learning methods are being used in combination with satellite images and aircraft scanning data to enhance monitoring and forecasting of ice cover and forest resources. They are likewise being used to identify biodiversity in images captured by trail cameras and to reduce human error in data analysis (EC, 2021).

France is similarly applying AI to advance official environmental statistics and land monitoring. The National Mapping Agency (IGN) is developing AI systems for land cover analysis using aerial and satellite imagery. Its CoSIA tool (Cartographie par Observation Spatiale d'Intelligence Artificielle) supports detection of land cover changes, analysis of urban nature and mapping of ecological corridors. All AI training datasets and pre-trained models are released as open source, enabling adaptation to other territories and themes. The outputs contribute to the European AIML4OS project, which aims to establish shared AI-based methods for producing official statistics.

Increasing access to Earth observation data: Expanding Earth observation coverage and international data-sharing collaborations can significantly improve monitoring of underrepresented regions. At the international level, strengthening initiatives and partnerships such as the European-African Space Partnership and Space in Africa can enhance data availability and integration. Open-data initiatives from NASA and ESA (Copernicus) have already improved global accessibility, while private-sector innovations such as Planet Labs microsatellites and the EDF methane satellite demonstrate how emerging technologies can provide higher-resolution, real-time monitoring. International agencies can also implement capacity-building initiatives to help countries integrate EO data into national environmental assessments and decision-making. At national level, increasing governments and private sector participation in Earth observation efforts can help ensure that decision-makers, researchers and local communities have access to the data they need for climate monitoring, biodiversity assessments and disaster response. National institutions can also benefit from engaging with open-data platforms and forging partnerships that enable the uptake of high-resolution Earth observation tools in national monitoring systems.

Improving dataset reliability and precision through triangulation and data fusion: Triangulation methods combine independent datasets to improve accuracy and resolution, and can be applied at both national and international levels. Combining satellite observations with in situ measurements enables interpolation of missing data points and higher-resolution environmental monitoring, making it possible to track pollution levels, biodiversity shifts and climate impacts with greater accuracy. Furthermore, integrating ground-based monitoring, EO data and citizen science records provides a basis for data authentication, strengthening dataset validity. Creating decentralized authentication systems, where data exchanges triangulate environmental data from different sources, would enhance the transparency and reliability of national and international environmental reporting and modelling. Developing international protocols or guidance for the use of global datasets, citizen science and modelled outputs in cases where official national data is unavailable would help ensure transparency, comparability and proper contextualization.

Expanding the scope of corporate disclosures: Improving the availability and reliability of ESG data requires coordinated interventions at national and international levels. National governments have a central role in setting regulatory requirements, expanding disclosure mandates to include high-impact SMEs, especially in sectors like agriculture, transport and energy. They can further operationalize ESG reporting developing needed digital infrastructure, guidance tools and enforcement mechanisms. However, these efforts must be aligned with international frameworks and norms to avoid fragmentation across jurisdictions. At the product level, governments can move towards a disclosure model in which certain core product-level environmental data (e.g. embedded carbon content, recyclability or hazardous materials) are mandatory, with a progressive and modular approach to increase ambition. Voluntary disclosures can still play a role but should be structured and interoperable with regulatory systems. Pilot initiatives under the Global Framework for Digital Product Information Systems and the UN Transparency Protocol can help in developing scalable models for disclosure frameworks.

Strengthening the role and credibility of citizen science and local data collection: Citizen science can help bridge gaps in environmental datasets, providing highly granular, real-time data from local communities. Governments and national agencies can support the adoption of QA/QC protocols and invest in AI-powered validation systems that cross-check observations against authoritative datasets, providing confidence scoring and filtering out unreliable data. In Norway, for example, when experts or citizens submit species observations to the national biodiversity data information system, Artsdatabanken, the records are verified and annotated with the observer's identity, method of observation, and confidence level. This approach provides transparency and allows users to know the origin and reliability of the information. Norway has also initiated research programmes aimed at encouraging and improving citizen science data collection (NTNU, 2025).

Governments can also explore opportunities to unlock new local data sources, such as using mobile phone tower readings to support weather monitoring. NGOs also play an important role in connecting with marginalized communities and bridging data gaps, for example by promoting the use of low-cost monitoring networks. Their role can be strengthened by ensuring that community-generated environmental data meets FAIR and OGC standards. At international level, platforms like GBIF and iNaturalist already validate user-submitted biodiversity data, and expanding these QA/QC mechanisms across other environmental domains (e.g., air pollution, waste management and deforestation) would enhance credibility. International guidance on how to collect citizen science data, together with tools that support standardized data entry and metadata tagging, would help increase data quality and comparability. Developing data translation frameworks and standardizing community-driven datasets can enhance their usability in national and global environmental data systems.

Box 5.2 GRID: a distributed model for quality-assured environmental data sharing

The Global Resource Information Database (GRID) network, established by UNEP in the mid-1980s, provides distributed environmental data governance built on shared standards, technical expertise and institutional collaboration. GRID centres were set up in diverse global regions and link to a rich network of scientific institutions and data providers. GRID centres serve as regional hubs for collecting, validating, analyzing and disseminating environmental data. By applying consistent quality assurance protocols, metadata standards and geospatial methods, they enhance the credibility, comparability and usability of datasets across regions. Their role also includes packaging complex environmental data into decision-relevant formats for policymakers and the public, building trust and promoting accessibility.

Crucially, GRID's structure helps bridge global and local data systems, ensuring that environmental information reflected both international norms and regional realities. In particular, GRID demonstrates the value of investing in regional capacities, technical standards and institutional coordination to ensure the quality, provenance and accessibility of environmental data at scale.

Strengthening standards on data collection, processing and QA

Challenges

Environmental data is only as reliable as the protocols and standards that govern its collection, processing and validation. Poor environmental data limits the ability downstream to effectively utilize it, including for training AI systems. Weak, inconsistent or absent standards create gaps in data availability, reduce quality and limit comparability across regions and institutions. There is also a lack of international processes and frameworks to vet and authenticate the most reliable sources of environmental data and their provenance. This undermines trust in environmental data and its utility for policymaking and research.

Inconsistent data collection and processing protocols: Environmental data are collected using diverse methods and technologies. Different countries and organizations apply varying sampling techniques, measurement tools and collection frequencies, making it difficult to merge datasets into a coherent global picture. For example, data from earth observation satellites can be hard to integrate if the instruments do not follow the same specifications. Many real-time systems, such as air quality and hydrological monitoring networks, operate on different time scales and resolutions, creating challenges for harmonization.

Biodiversity monitoring often relies on different approaches to species identification and population counts, making it hard to compare trends across regions. DNA-based environmental data lack clear acquisition and analysis standards, resulting in datasets that cannot be reliably integrated into global biodiversity assessments. Solid waste data also illustrate these challenges clearly. In many countries, statistics are inconsistent due to the lack of harmonized definitions between municipal and non-municipal waste, as well as disparate collection methodologies between national and subnational governments. As a result, official data often underestimate waste generated outside urban areas or by industrial and informal actors.

Critical details are often lost when transitioning from raw observations to published datasets, complicating bias assessment and reliability. Inconsistent data transformation practices can also create misalignments. For example, cleaning, interpolation and normalization processes vary based on local needs and preferences. Two datasets measuring the same phenomenon may produce contrasting results due to differences in the way they were processed. In statistical offices, reliance on administrative data collected by multiple agencies with different mandates and definitions leads to further misalignments. The result is a global environmental data ecosystem where datasets are difficult to integrate, compare or validate.

Weak and incoherent methodologies and standards for corporate disclosures: Many environmental impacts and supply chains are transboundary, and the lack of alignment in definitions, reporting formats and data standards undermines the comparability and credibility of ESG disclosures. Disclosure frameworks such as the Carbon Disclosure Project, the Global Reporting Initiative and and ESRS impose differing requirements and definitions, particularly in complex areas such as Scope 3 emissions and nature-related impacts. Even among companies that report on sustainability, key metrics (e.g. biodiversity impacts or value chain emissions) are often missing, poorly estimated or based on inconsistent methodologies. In many cases, companies rely on proxy or industry-average data, especially for Scope 3 emissions, obscuring real differences in performance and reducing the usefulness of disclosures for traceability, procurement, or investment decisions.

Product-level environmental data, including carbon footprints, recyclability scores and emerging tools like digital production information systems, are also increasingly critical for sustainability claims, trade regulations and consumer information. Yet there is currently no globally harmonized framework for structuring, validating or exchanging such data. Life-cycle assessment methodologies differ significantly across sectors and regions, while emissions calculations often rely on non-standardized assumptions and input data. This limits the comparability, credibility and scalability of product-level disclosures and hampers their integration into both regulatory systems and private sector sustainability strategies.

Inconsistent adoption of quality assurance and validation standards: A number of important global data quality frameworks exist, notably ISO 8000 on data quality, ISO 19157 on geospatial data quality, SDMX on statistical data exchange, INSPIRE on EU geospatial standards and OGC geospatial standards. In practice, however, implementation varies widely. Some governments and organizations lack formal quality assurance and validation processes, leading to datasets with missing values, errors and inconsistencies. In other countries, funding limitations and reliance on short-term staff weaken quality assurance processes. In the private sector, environmental data reporting often lacks standardized quality controls, raising concerns about greenwashing, unverifiable claims and data manipulation, particularly in voluntary sustainability disclosures.

Challenges defining and implementing data quality standards across use cases: Global data quality standards are difficult to enforce universally because data quality requirements vary substantially based on use case. For example, regulatory enforcement demands highly precise, legally defensible data, whereas scientific research and public reporting may allow for greater flexibility in uncertainty and accuracy thresholds. Existing standards such as ISO 19157 and SDMX acknowledge these differences by providing adaptable quality frameworks. However, balancing robust quality control with practical feasibility remains a challenge, particularly in resource-constrained regions where complex and expensive quality requirements may limit participation in global environmental monitoring efforts.

Responses

Addressing inconsistencies in environmental data collection, processing and validation requires action to strengthen scientific data collection and assessment protocols and to enhance sensor calibration, data verification, quality thresholds, decentralized validation and public digital infrastructures.

Strengthening scientific data collection standards and assessment protocols: High-quality environmental data depends not only on what is measured but also on how it is measured. While many environmental domains have developed strong technical standards, such as WMO guidelines for climate, others remain fragmented or lack internationally recognized methods. There is no consolidated global framework covering sampling strategies, analytical techniques, uncertainty estimation, detection limits or reporting formats across domains. To improve the quality, comparability and integration of environmental datasets, UNEP and its partners could play a convening role by mapping existing benchmarks and facilitating the co-development of "gold standard" methodologies. These reference frameworks would promote methodological consistency while allowing for contextual adaptation. Clear guidance on best practices would strengthen both scientific integrity and policy relevance, particularly in areas with emerging methods or uneven uptake. Where possible, efforts would build on and align with ongoing initiatives, such as those led by IPBES, WMO and ISO, to maximize coherence and avoid duplication.

Develop and enforce protocols to test and calibrate environmental sensors: Networks of environmental sensors, especially low-cost ones, need calibration and independent validation of accuracy, consistency and precision before their data can be federated into global datasets. At national level, regulatory agencies can develop and enforce protocols to test sensors, and ensure that calibration settings, error bars and confidence levels are documented in metadata so that users can assess reliability. At the international level, standard-setting bodies and technical networks can support these efforts by promoting shared calibration guidelines and metadata standards.

Box 5.3 Standardizing eDNA data collection and analysis methods

Consistent environmental monitoring requires standardized methods for data collection and analysis. Without common protocols, datasets may lack comparability, leading to discrepancies in research findings and policy assessments. Expert working groups can help advance methodological harmonization. For example, the International eDNA Standardization Task Force brings together brings together members of the environmental DNA community to align data collection methods for DNA analysis. This initiative contributes to international standardization efforts within ISO (ISO TC 147/SC5/WG13).

Harmonizing ESG reporting standards and product-level disclosures: To improve the comparability, credibility and utility of ESG disclosures, there is a pressing need for greater international harmonization of standards. At the entity level, alignment is needed across non-financial reporting frameworks, which currently differ in definitions, metrics and scope, particularly for complex areas like Scope 3 emissions and nature-related impacts. At the product level, global guidance is needed to establish consistent, interoperable standards for digital product information systems and to align life cycle assessment (LCA) methodologies. Developing sector-specific environmental baselines, akin to the Codex Planetarius in food and agriculture, could help define common expectations and facilitate both compliance and sustainable trade. International initiatives such as the UN Transparency Protocol, the EU Digital Product Passport, and UNEP FI's voluntary principles provide an important foundation for these efforts, supporting interoperability, guiding best practices, and helping ensure that both voluntary and mandatory disclosure systems evolve in coherent and mutually reinforcing ways. At the national level, governments have an important role in integrating international frameworks into domestic legal or voluntary disclosure systems, as well as customizing them to national priorities or contexts.

Invest in systematic QA/QC protocols and supporting infrastructure: Robust quality assurance and quality control processes are needed to ensure that datasets are representative and scientifically sound. At the national level, agencies can implement protocols that include bias detection, consistency checks and cross-validation of data sources. QA checks should systematically identify potential distortions, such as the overrepresentation of specific regions, species, or demographic groups. To support harmonized implementation, there would be value in international efforts to compile an overview of existing manuals, guides, best practices and methodologies for QA/QC across environmental domains. For example, ODIS (2025) has already developed such a repository for ocean data, which could serve as a model for other sectors.

At the international level, uptake of QA protocols can be further promoted by creating open-access digital infrastructures and public data markets that require datasets to meet quality and compliance benchmarks before dissemination. Establishing regional or domain-specific data validation hubs can help authenticate environmental data quality before integration into larger datasets. Existing platforms like GBIF (for biodiversity data) and OBIS (for oceanographic data) already serve as data brokers, ensuring quality control through structured validation and metadata standards. The UNECE Pollution Release and Transfer Register system already automatically queries submissions of contradictory or questionable data (e.g., identical submissions from previous years), improving the quality of reported environmental data. Integrating automated QA systems with global clearinghouses would strengthen compliance, allowing environmental data to be independently verified while also remaining discoverable, interoperable and reusable across platforms.

Box 5.4 Operationalizing data standards: the Climate Change Knowledge Portal

The World Bank's Climate Change Knowledge Portal (CCKP) illustrates how the systematic application of established scientific standards can enhance the usability and credibility of environmental data. Drawing from leading scientific sources, the CCKP adheres to internationally recognized protocols, including those from the World Meteorological Organization (WMO) and technical guidance from the IPCC Assessment Reports. By consistently applying transparent methods for data processing, post-processing and presentation, the CCKP ensures that datasets are inter-comparable across sectors and geographies. This fosters confidence among users and enables the data to support a wide range of applications.

Establishing and operationalizing data quality standards: High-quality environmental data depends on both the establishment of global reference frameworks and their effective operationalization through national implementation and sectoral adaptation. At the international level, structured frameworks such as FAIR principles and ISO 8000 standards provide guidance on data governance, validation and accessibility. ISO 8000's focus on data quality, standardization and integrity supports sensor calibration, QA/QC protocols and tiered data quality standards, ensuring that datasets remain accurate and usable over time. However, the cost and complexity of implementing ISO 8000 can pose barriers, particularly in low-resource contexts, underscoring the need for scalable and context-appropriate approaches. Meanwhile, the FAIR principles enhance the accessibility, interoperability and reuse of environmental data, making it easier for researchers, policymakers and the public to find and trust high-quality datasets.

To put these frameworks into practice, governments can require public agencies, research institutions and private entities handling environmental data to meet minimum quality standards aligned with global frameworks such as ISO 19157, SDMX and OGC geospatial standards. Minimum compliance thresholds could cover dimensions such as accuracy, metadata and provenance. However, recognizing that data requirements vary across regulatory, scientific and public reporting domains, governments and international organizations could develop sector-specific guidelines and toolkits that adapt the implementation of these standards to different use cases. Communities of practice, bringing together practitioners, researchers, policymakers and data managers, could help in defining such guidance.

Box 5.5 Use of FDES to assess and improve environmental data quality in Zanzibar

Zanzibar has adopted the UNSTAT Framework for the Development of Environmental Statistics (FDES) (UNSTAT, 2013) to systematically assess and improve its environmental data quality, ensuring alignment with international standards. This approach helps harmonize data collection and processing, making environmental data more reliable for policy and decision-making. By using an internationally recognized framework, Zanzibar is strengthening the consistency and comparability of its environmental data.

Ensuring transparency and provenance tracking

Challenges

Ensuring the accuracy, reliability and transparency of environmental data requires robust provenance and lineage tracking to document where data comes from, how it has been processed and how it has been modified over time (i.e. the data life cycle). Inadequate tracking mechanisms, duplication of datasets and opaque AI-driven transformations make it difficult to verify the authenticity and quality of environmental data.

Incomplete and inconsistent metadata: Metadata is essential to understand the origins, methods, reliability, accuracy and usefulness of datasets. Information about how, when and by whom data was collected are critical for ensuring data integrity and comparability. However, many datasets fail to document collection methods, update timestamps, calibration settings and analytic assumptions, reducing their value for research and policy applications. As discussed in more detail under Pillar III on Interoperability, metadata standards also vary significantly between environmental domains, institutions and countries. The absence of consistent metadata increases risks of misinterpretation or misuse of data and necessitates that researchers and others divert time and resources to verifying data quality. Standardized and consistent metadata are also essential for integrating datasets across different platforms and institutions, and aggregating national-level data into global reporting frameworks.

Uncertainties about data lineage: Datasets are often siloed across different institutions and lack detailed provenance tracking, meaning users cannot determine how the data was collected, processed, or modified over time. While this often reflects gaps in metadata, provenance tracking also depends on other kinds of logs, including version histories, processing records and access controls. The problem can be particularly acute for datasets that combine multiple sources, as researchers and policymakers may be unable to verify the accuracy of the original data or the assumptions behind its processing. Licensing restrictions and limited access to raw data can further hinder transparency, preventing users from verifying how data has been aggregated or altered.

Duplication and divergence of datasets: Many environmental datasets exist in multiple versions across different platforms, often with slight variations due to updates, transformations or data cleaning processes. In some cases, multiple copies of the same dataset evolve in different ways, leading to conflicting versions of environmental indicators. Without governance mechanisms to establish authoritative versions of key datasets it is difficult for researchers or decision-makers to identify the most accurate and up-to-date data source.

Opacity of AI models: Uncertainties about data provenance are compounded by AI-driven data transformations, where black-box models process data without clear documentation of their logic. Without clear documentation of model parameters, training datasets and decision-making logic, AI-driven environmental analysis may become increasingly opaque. Additionally, AI-generated content could amplify misinformation if not properly labelled and documented.

Limited traceability of embedded environmental impacts in supply chains: Even where emissions factors and estimation methodologies exist, companies often lack access to reliable, granular data on the materials, energy inputs and environmental impacts associated with individual products or components. The absence of standardized product-level reporting and digital traceability tools makes it difficult to calculate embedded emissions, water use, or biodiversity impacts, especially across multi-tier supplier networks or where informal actors play a significant role. Traceability is even lower for bulk-traded commodities such as grains, fuels and metals, where materials from multiple sources with different sustainability characteristics are mixed. This practice obscures the origin and environmental attributes of products, increasing the risk of misrepresentation or greenwashing in sustainability claims.

Responses

Ensuring environmental data accuracy and transparency requires robust provenance and lineage tracking to document where data comes from, how it has been processed and how it has been modified over time.

Strengthening data traceability and transparency: Improving traceability requires clear documentation of the entire data pipeline, from collection and transformation to analysis and decision-making. National and international effots to adopt common provenance standards such as Open Provenance Model (OPM), PROV-O and W3C PROV would help ensure consistency across datasets.

Metadata should clearly document collection methods, processing algorithms, data transformations and calibration settings. Further including error margins, confidence levels and uncertainty ranges can help ensure that users can evaluate the reliability of datasets for different applications. AI-generated data and models must include comprehensive metadata on training datasets, model parameters and transformation methods in order to limit opacity and ensure accountability in AI-based environmental assessments. Metadata tagging using standards like ISO 19115, DCAT and schema.org ensures that provenance information is machine-readable and consistently applied across platforms. National actions could be supported by global efforts to develop guidelines for AI-generated data transparency, including documentation of training datasets, transformation methods and decision logic.

Facilitating automated provenance data collection: Data collection systems (e.g., sensors, remote sensing, IoT devices) can automatically generate metadata alongside raw data. Automating the collection of provenance variables such as time and location of data capture, sensor calibration data, sampling frequency and environmental conditions during collection can ensure provenance tracking and minimize human error. Data management platforms (e.g. Open Data Cube) can also enforce metadata entry, ensuring that necessary provenance information is recorded and maintained.

To further protect dataset integrity, secure access controls can be implemented within automated data pipelines to limit unauthorized modifications or tampering at the point of collection. Multi-factor authentication (MFA) and cryptographic verification methods can help ensure that only authenticated sources contribute data to official repositories. Additionally, maintaining secure audit trails to log all dataset modifications, transfers and access events helps ensure a verifiable history of dataset interactions.

Using available tools to decentralize data lineage tracking: A variety of tools can be used to limit dataset duplication, divergence and inconsistencies. For example, designating trusted global or regional repositories as authoritative repositories for key datasets can prevent uncontrolled duplication and conflicting versions. Assigning globally unique identifiers (DOIs) through the DOI Foundation or CrossRef eliminates confusion about dataset origins and versions. Using ORCID IDs for researchers and contributors enhances attribution and accountability, linking datasets to verified authors and institutions.

Digital signatures can further certify dataset authenticity, ensuring that environmental data remains unchanged from its source. Combined with blockchain or distributed ledger technology, this can create tamper-proof records of data provenance while ensuring that updates are securely verified. Additionally, APIs can be used to synchronize distributed copies of datasets so updates of the authoritative dataset are reflected in all versions.

The European Open Science Cloud (EOSC) offers a useful reference point, providing a federated infrastructure for open data access and provenance tracking across scientific domains. EOSC's experience with metadata standards, persistent identifiers and governance mechanisms is directly transferable to environmental data contexts.

Aligning data policies with AI applications: As AI plays a larger role in data transformation, integration and modeling, environmental data policies should ensure accountability, transparency and provenance tracking to maintain scientific integrity and regulatory compliance. For example, AI models used in environmental monitoring should document decision-making logic, dataset parameters and processing methods. Metadata should include persistent DOIs, machine-readable formats and structured data lineage tracking to improve AI-driven data integration and validation.

Enhancing transparency and accountability in product supply chains: Strengthening transparency in corporate environmental claims and carbon markets requires robust regulations (including requirements for product-level disclosures), standardized reporting and advanced tracking technologies to ensure data is verifiable, auditable and comparable. Establishing legally binding sustainability disclosure frameworks like the EU Corporate Sustainability Reporting Directive is an important driver for wider corporate reporting. Digital Product Information Systems, like those adhering to the Global Framework for Digital Product Information Systems or the UN Transparency Protocol, provide an essential complement to disclosure laws by offering a secure means to track environmental footprints, material use and other impacts across value chains, preventing greenwashing and unverifiable claims. Public registries, third-party certification and standardized emissions reduction methodologies are also essential measures to prevent fraudulent offsets and misuse of funds. By helping ensure that carbon markets contribute to genuine climate action, they also preserve trust in the global environmental data ecosystem. Lastly, the continuing work of UNEP's Life Cycle Initiative over more than two decades has enhanced consensus around impact assessment methods used in Life Cycle Assessment (LCA) studies, increasing the reliability and consistency of LCA.

Developing national "guarantee-of-origin" systems for bulk commodities: Guarantee-of-origin schemes provide a trustworthy, auditable framework for mass-balance accounting at facilities managing mixed-source materials. They can help track sustainability attributes across processing stages, even where physical segregation is impractical. Existing examples include the European Energy Certificate Scheme, the Forest Stewardship Council's chain of custody standards, and the UTZ Certified coffee traceability system.

Preserving confidence and trust in environmental data

Challenges

In the absence of broadly accepted trust frameworks and transparent validation mechanisms, concerns over data reliability and completeness undermine confidence in environmental datasets.

Diverse drivers of loss of trust: As previously noted, issues such as missing metadata, unclear data lineage and dataset duplication contribute to distrust in environmental monitoring systems. Without mechanisms to verify authenticity, track modifications and ensure transparency, environmental data remains vulnerable to misinterpretation and skepticism. The growing use of AI makes it increasingly hard to distinguish between real, manipulated or entirely fabricated data.

Concerns about greenwashing: Much corporate environmental data is self-reported and unaudited, contributing to risks of greenwashing and inconsistent data quality. In most cases, companies are not required to provide evidence or documentation to support their disclosures and there is no obligation to link claims to underlaying datasets or methodologies. The absence of formal verification frameworks for product- and entity-level disclosures undermines trust, comparability and enforcement. The level of scrutiny and review of available LCA datasets varies widely between data providers, limiting the extent to which available data can be easily used.

Marginalization of indigenous and local knowledge: Social and structural factors also play a role in shaping trust in environmental data. The marginalization of Indigenous and local knowledge reduces both the completeness and acceptance of datasets, as communities that contribute valuable environmental insights often see their perspectives excluded. More inclusive data governance that integrates diverse knowledge systems could enhance both the credibility and usability of environmental information.

Conflicting messages from different data sources: Inconsistencies in data resolution, measurement techniques and methodological assumptions mean that datasets assessing the same environmental risk may produce varying interpretations and conclusions, leading to public confusion. For example, in air quality monitoring, ground-based sensor data provides highly accurate local readings, while satellite-derived estimates offer broader but less precise coverage. When global platforms prioritize coverage over accuracy, higher-quality local datasets can be overlooked, creating situations where different sources present conflicting levels of risk to the public.

Responses

Many of the actions set out in Sections 3.2.1-3.2.3 (e.g. addressing gaps and biases, improving quality assurance and increase transparency) would increase trust in environmental data. Further measures include establishing dataset accreditation and certification systems, accommodating user feedback tools, empowering data providers with licensing control and incorporating indigenous and local knowledge.

Establishing independent validation and audit mechanisms: Building trust in environmental data also requires strong institutional safeguards. Trust depends not only on technical quality but also on the independence and transparency of the institutions producing the data, and on the participation of civil society and academia in the validation process. Manipulation of figures for political or commercial purposes must be actively prevented. Establishing multi-actor data audit mechanisms, particularly for high-impact or politically sensitive domains, can strengthen data credibility, reinforce public confidence, and ensure accountability. In Norway, for example, the Statistics Bureau and the Environment Agency are jointly responsible for producing environmental statistics and their dual sign-off provide an extra layer of credibility and impartiality, reinforcing public confidence that the numbers are robust and not biased.

Establish robust verification and assurance systems for corporate environmental data: Verification and assurance mechanisms can reduce greenwashing and strengthen confidence in sustainability claims. Independent third-party audits, standardized reporting methodologies and public disclosure of verified data can help ensure that corporate claims, such as carbon neutrality or eco-labels, are accurate, comparable and enforceable. Using AI and cryptography-enabled tech to automatize the verification process can also reduce costs while not compromising assurance levels. These mechanisms should align with international standards and be applied consistently across sectors and jurisdictions.

Certifying high-quality data repositories and engaging users: Applying globally recognized trust certification standards such as CoreTrustSeal for environmental data repositories ensures that datasets are curated, maintained and stored in a transparent, verifiable and standardized manner. Incorporating user feedback tools such as reviews and usage statistics on open data platforms can further increase transparency by showing how datasets are used, verified and valued by the community.

Recognizing and incorporating indigenous and local knowledge: Establishing protocols for integrating traditional knowledge while maintaining transparency in its use and limitations can help ensure credibility and respect for community insights. Indigenous communities should retain control over how their data is used and shared, ensuring that their contributions to environmental monitoring are both protected and valued. Engaging indigenous and local experts in environmental assessments, advisory councils and validation processes, ensuring their knowledge is not just collected but actively applied (see also 4.4.2).

Box 5.6 Strengthening transparency through reporting frameworks such as ETF

The Enhanced Transparency Framework (ETF) under the Paris Agreement aims to improve trust in climate and environmental data by establishing robust, internationally agreed reporting mechanisms (UNFCCC, 2025). ETF requires countries to submit Biennial Transparency Reports, ensuring that climate data are regularly verified, openly available and structured according to clear methodological guidelines. UNEP supports countries in adopting the Enhanced Transparency Framework by providing technical and financial support for reporting and support for high-quality, credible, open climate and environmental data, information, statistics, as well as scientific assessments and expertise (UNEP, 2023).

Aligning data generation with decision-making needs

Challenges

In many instances, environmental data generated through monitoring systems, academic research and corporate reporting fail to meet the needs of decision-makers. This misalignment can occur because the wrong questions are being asked, datasets are not tailored to national or local needs, or critical information remains inaccessible or lacks sufficient granularity.

Collected data misaligned with policy needs: In some cases, environmental monitoring focuses on the wrong variables, making it difficult to inform effective policies and actions. For example, in ecosystem restoration, data collection often prioritizes species diversity, whereas tracking ecosystem functions may provide a more accurate picture. Datasets may also lack essential attributes that would improve their usability. For instance the absence of geotagging can significantly limit the usefulness of data on forest conditions and trends for spatial analysis, research and policy applications.

Lack of actionable data from academic research: While academic research generates valuable environmental insights, the data produced is often not designed for real-world application. The traditional research funding model prioritizes publications over practical solutions, meaning that many datasets are created for academic purposes rather than for decision-making, policy development, or environmental management. To the extent that environmental research produces valuable data, it is often siloed within academic or institutional circles, where it cannot be accessed for practical application (see Pillar IV).

Global Earth observation data misaligned with national needs: Global Earth observation datasets can play an important role in filling gaps in environmental monitoring but they are often not designed to meet the specific needs of national or local governments. Decision-makers require data that aligns with administrative boundaries and policy priorities, yet EO datasets may lack the necessary resolution, specificity or contextualization. A validation system that allows governments to integrate EO data into national reporting when official data is missing could help bridge this divide.

Insufficient data inputs for credible corporate environmental reporting: Companies rely on both public datasets (e.g. emissions factors, water stress indices, land-use data) and information from upstream suppliers to calculate Scope 3 emissions, product footprints and ESG metrics. In many cases, public datasets are outdated, poorly disaggregated or missing altogether, forcing companies to use global or national averages that lack regional specificity. At the same time, companies often struggle to gather reliable environmental data from suppliers, particularly in complex, multi-tier supply chains. Together, these gaps undermine the credibility, comparability and usefulness of corporate sustainability disclosures and limit their value for decision-making, regulation and green finance.

This issue is becoming more urgent as regulatory frameworks such as the EU's Ecodesign for Sustainable Products Regulation (ESPR) begin to require detailed, verifiable product sustainability information. Without access to high-quality, localized public reference data, companies risk producing fragmented or non-compliant disclosures. This risks weakening transparency, eroding public trust and hindering alignment with sustainability goals.

Responses

Identifying priority dataflows and indicators to meet decision-making needs: Aligning environmental data collection with the needs of decision-makers can be facilitated by identifying priority datasets that directly inform national policies, global targets and practical interventions. A set of core and non-core environmental indicators that can be adapted to national capacities and contexts would enhance data usability while ensuring consistency with international frameworks. Existing regional initiatives provide a starting point for developing a priority set of indicators. These include, for example:

- the UNECE priority indicators for the pan-European region (UNECE, 2023);
- the UN Statistics Division's Basic Set of Environment Statistics (ref), which aims to support countries developing national environment statistics programmes by identifying priorities;
- the set of indicators developed by the Secretariat of the Pacific Regional Environmental Programme for state of environment reporting in Pacific island countries (SPREP, 2021a);
- the 22 indicators of the UN Regional Seas Programme (ref);

- the State of Nature metrics under the Nature Positive Initiative, which offer a globally coherent yet flexible approach for tracking biodiversity outcomes aligned with the Kunming-Montreal Global Biodiversity Framework (ref).

In defining indicators, there is a need to balance comprehensiveness with feasibility to help ensure that a minimum set of indicators is achievable by all countries. Ensuring that environmental datasets account for local priorities, governance needs and administrative boundaries, allowing for greater policy relevance. For example, the UNECE priority indicators aim to align data collection efforts with major sustainability goals such as the SDGs, Paris Agreement and Sendai Framework to support global reporting while maintaining national applicability. Similarly, tools such as the CGDI Analysis-Ready Data (ARD) Starter Kits help operationalize satellite data for national use, lowering technical barriers and increasing the accessibility of high-quality geospatial data for indicator development and reporting (ref).

International and regional organizations play a valuable role in translating complex scientific datasets into accessible, policy-relevant formats. For example, UNEP/GRID-Arendal helps developing countries interpret, apply and communicate environmental data effectively. Strengthening the capacity of such institutions can support broader data democratization and empower national and sub-national actors to make informed decisions.

Shifting academic incentives to produce more actionable data: Incentivizing academic institutions to prioritize practical applications and data sharing can help ensure that research delivers actionable, decision-ready data for policymakers and practitioners. This could mean encouraging funding bodies to reward research that contributes directly to environmental management, policy development and real-world problem-solving. It could involve working with funding agencies and journals to agree and implement rules requiring datasets to be openly available and well-documented. Promoting the uptake of data usage metrics and indices, for example by making dataset impact tracking part of research grant evaluations, could also help ensure that data are findable, accessible, interoperable and reusable.

Aligning Earth observation data with national needs: Several approaches can enhance the relevance of EO datasets. These include developing workflows to transform global EO data into national datasets aligned with administrative and policy needs; taking advantage of analysis-ready data (ARD) frameworks such as Digital Earth Africa (DEA, 2025) and CEOS ARD (CEOS, 2025), which pre-process EO data to fit user requirements; and promoting coordinated regional approaches, such as SPREP's in the Pacific region, which translates EO data into products attuned to the need of national governments. The US offers a best practice example of how to validate EO data for evidence-based decision-making in a streamlined manner. In particular, the 2019 National Plan for Civil Earth Observations provides a structured approach to integrating and prioritizing EO data across different government agencies and policy domains.

The concept of analysis-ready data extends beyond satellite imagery, encompassing any dataset that is pre-processed, quality-assured, and formatted for direct use in decision-making. For environmental policy and impact assessment, this broader ARD approach is essential to ensure that disparate data sources can be used reliably and rapidly.

Addressing the environmental data needs of businesses: Improving access to high-quality environmental and Earth observation data is essential to support corporate sustainability efforts, supply chain risk assessments and innovation. Governments can contribute by developing standardized, business-friendly data tools, such as national emissions factor databases or water risk maps, that align with international protocols. For example, the Dutch CO_2 Emission Factors Database provides a trusted resource to support consistent corporate GHG reporting. At the international level, open access to geospatial and environmental monitoring data remains a critical enabler of Scope 3 emissions tracking and ESG reporting.

Disaggregating corporate sustainability reporting: Standards bodies and regulators can encourage greater disaggregation in corporate reporting, including data breakdowns by facility, geography and product line. Frameworks and tools already exist to support this process. For example, implementing Pollutant Release and Transfer Registers (PRTRs) can provide high-resolution, facility-level reporting, and promote alignment with ESG and product-level frameworks to improve traceability and comparability. The UNTP Digital Facility Record provides a key facility-level reporting bridge between corporate and product level reporting. In parallel, UNEP FI's impact analysis tools (e.g., Impact Radar, Sector Impact Maps) also promote granular disaggregation of environmental risks and dependencies by sector and geography (UNEP, 2024).

Responding to the need for integrated data and assessments

Challenges

Environmental challenges are deeply interconnected with social and economic systems, yet current environmental data ecosystems struggle to integrate information across these domains. The absence of coherent frameworks, interoperability standards and comprehensive datasets limits the ability to conduct integrated and systemic assessments, making it difficult to analyse trade-offs, assess risks and support holistic policymaking.

Difficulties integrating environmental, social and economic data: Understanding and addressing systemic sustainability challenges requires a data ecosystem that connects environmental, social and economic factors. For example, integrated assessments, such as UNEP's GEO reports, increasingly use system-based approaches that combine environmental indicators with data on economic activity, innovation, social change and policy implementation at different scales of governance. In practice, however, absent data and weak integration across environmental, social and economic domains limits the ability to conduct systemic assessments and craft integrated policy responses to sustainability challenges.

Inability to communicate the social and economic implications of environmental change: Translating environmental data into policy and action often requires evidence and analysis about the broader impacts of environmental change. Explaining the impacts of air and water pollution, ecosystem disruption or zoonotic diseases on health, well-being and environmental justice is a powerful way to engage the public and decision-makers. Yet countries often lack the needed data, frameworks and examples of good practice to link environmental data with human well-being metrics.

Responses

Tackling systemic sustainability challenges require interconnected data systems that link environmental, social and economic factors. Strengthening cross-domain data integration, linking environmental data to human well-being and expanding the role of integrated assessments can all improve evidence-based policymaking.

Strengthening cross-domain data integration: Breaking down silos between environmental, social and economic data systems is critical for holistic decision-making. Interdisciplinary collaboration and coordinated research networks can help bridge gaps and integrate datasets across sectors. These efforts help ensure that environmental monitoring is integrated into broader economic, health and policy discussions. Alongside national efforts, emerging global initiatives like the World Bank's Livable Planet Observatory can facilitate access to cross-sectoral datasets while supporting AI applications, digital monitoring, reporting and spatial planning. To support uptake, countries and development partners could identify and publish best practice examples of integrated knowledge systems such as those outlined in Box 5.7. Regional workshops and training would help governments replicate successful models.

Box 5.7 Cross government coordination in New Zealand, France and the US

National initiatives like New Zealand's Climate Data Programme demonstrate the value of cross-agency coordination in overcoming inaccessible and siloed data sources, federating datasets without disrupting data stewardship. The initiative aims to create comprehensive climate data views by consolidating climate data across central and local government, and then to add value by integrating socio-economic, land use and private sector data with climate emissions, risk and adaptation data. In the US, the Global Change Research Programme, mandated by the Global Change Research Act of 1990, likewise provides a model for formalizing national-scale coordination across agencies like NOAA, NASA and the EPA. And in France, the Green Data For Health initiative creates a data space for environmental health research, as part of the 4th National Environmental Health Plan. The primary objective of this data hub is to enhance the discovery, use and alignment of environmental datasets with the needs of environmental health research.

Linking environmental data with human health, well-being and justice: integration of environmental and public health datasets allows policymakers to assess the impacts of pollution, climate change and ecosystem degradation on human well-being. Strengthening the connection between environmental quality and food security is equally critical, given that ecosystem health underpins agricultural sustainability. Furthermore, integrating environmental data with socio-economic and demographic datasets helps identify disparities in exposure to environmental risks, improving equity-based policymaking. Countries such as the United States have developed robust environmental justice frameworks, linking environmental datasets to socio-economic indicators to assess and address vulnerabilities. Expanding such approaches globally could enhance efforts to address environmental inequality and inform targeted interventions. International and regional organizations can support national efforts in this area by developing tools to help countries integrate environmental justice indicators into national monitoring systems, including geospatial mapping of disparities in exposure to pollution and climate risks.

Using integrated assessments to synthesize data and inform policy: Science-policy platforms like IPBES and IPCC provide successful models for synthesizing environmental, social and economic information into decision-making frameworks. Integrated assessments offer a structured approach for policymakers to analyze trade-offs and policy options. Japans ecosystem assessments, which synthesize available evidence rather than generating new datasets, highlight the value of leveraging existing platforms. Developing data systems that support integrated assessments will help navigate complex sustainability challenges and translate scientific knowledge into policy-relevant insights. To strengthen the role of integrated assessments, UNEP could enhance the data infrastructure underpinning its Global Environment Outlook (GEO) assessments, particularly by improving access to interdisciplinary data on complex human-environment systems and their dynamics, which remains a major gap in the current evidence base.

5.3 Summary of key responses

Table 5.1 summarizes the key actions proposed under each of the six thematic areas addressed under Pillar II, spanning both national and international levels.

Table 5.1 Summary of key actions to enhance data quality and transparency

Section	Key actions
2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets	• Implement routine data profiling and audit mechanisms at national and international levels. • Promote structured bias detection tools adapted from other domains (e.g. UNODC) for use in environmental data. • Use advanced technologies such as AI to augment quality control, anomaly detection and data harmonization across sources. • Expand access to Earth observation data and strengthen international data-sharing partnerships. • Apply triangulation and data fusion techniques to integrate satellite, in situ and citizen science data. • Develop protocols for using modelled outputs or global datasets when national data are missing. • Establish publicly accessible, machine-readable registers of data quality measures to improve transparency and consistent quality standards.
2.2.2 Strengthening standards on data collection, processing and QA	• Map and co-develop global minimum standards for scientific data collection, uncertainty reporting and analysis methods. • Develop and enforce calibration and testing protocols for environmental sensors, especially low-cost monitors, alongside reporting of results in provenance metadata. • Harmonize ESG reporting and product-level disclosure standards internationally.

	• Compile existing QA/QC guides and promote their uptake through national protocols and international validation hubs. • Operationalize data quality frameworks (e.g. ISO 8000) through minimum compliance thresholds and sector-specific guidelines. • Develop international guidance and tools to support standardized collection, metadata tagging and validation of citizen science data, enhancing quality, comparability and usability.
2.2.3 Ensuring transparency and provenance tracking	• Promote adoption of common provenance standards (e.g., PROV-aligned metadata, OPM) and their implementation in metadata markup (e.g., ISO 19115, schema.org, DCAT). • Automate provenance metadata capture through sensors, IoT devices and data management platforms. • Use digital signatures, DOIs, ORCID IDs and blockchain tools to certify dataset authenticity and trace lineage. • Ensure AI-generated data are transparent, with documented training sets, models and transformation methods. • Align environmental data policies with AI use, requiring structured metadata and traceability.
2.2.4 Preserving confidence and trust in environmental data	• Establish collaborative audit mechanisms and independent validation procedures for sensitive or prioritized datasets to strengthen transparency and confidence, while respecting national data ownership. • Build assurance systems for corporate environmental data, including third-party validation / verification and standardized reporting. • Certify repositories with trust standards like CoreTrustSeal and integrate user feedback mechanisms. • Recognize and incorporate measures to ensure CARE compliance for Indigenous data, with safeguards for community control and attribution. • Consult local communities to ensure their insights, needs and concerns are incorporated into quality assessments of data from their localities.
2.2.5 Aligning data generation with decision-making needs	• Define core and non-core environmental indicators that align with national policy priorities and global goals. • Establish shared data product specifications linking policy goals to data needs (e.g. flood risk maps) to guide relevant, efficient data generation. • Incentivize academic institutions to generate actionable, well-documented and open-access datasets.

	• Transform EO data into formats aligned with national administrative and policy needs (e.g., analysis ready data (ARD) frameworks). • Improve access to decision-relevant datasets for businesses (e.g., emissions factor databases, risk maps). • Promote granular, disaggregated corporate reporting through PRTRs, UNTP Digital Facility Record and UNEP FI tools.
2.2.6 Responding to the need for integrated data and assessments	• Strengthen cross-domain data integration through national coordination, interdisciplinary networks and platforms like the Livable Planet Observatory. • Link environmental data with health, food and socio-economic indicators to enable equity-focused policymaking. • Build the knowledge base for integrated assessments by strengthening data infrastructure, including an emphasis on complex human-environment systems and transformational change.

5.4 Overview of best practices in Pillar II

Example	Section
Estonia uses AI to enhance environmental monitoring and reduce human error.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
France's CoSIA tool uses AI to detect land cover changes and map ecological corridors, with open-source outputs for reuse.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
European-African Space Partnership, Space in Africa, NASA and ESA (Copernicus) strengthen monitoring globally by increasing access to EO data.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
GBIF and iNaturalist validate user-submitted biodiversity data, enhancing reliability and trust in citizen-generated data.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
Norway's Artsdatabanken verifies citizen science biodiversity data by tagging observations with identity, method and confidence level, improving transparency and usability.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
UNEP's GRID network provides distributed regional hubs for validating, packaging and disseminating environmental data using shared QA protocols and geospatial standards.	2.2.1 Addressing gaps, inaccuracy and biases in environmental datasets
The International eDNA Standardization Task Force works to standardize data collection methods for DNA analysis.	2.2.2 Strengthening standards on data collection, processing and QA
WWF Codex Planetarius is developing minimum environmental performance standards for internationally traded food, offering a model for other sectors.	2.2.2 Strengthening standards on data collection, processing and QA

The UNECE Pollution Release and Transfer Register system automatically assesses the reliability of submissions.	2.2.2 Strengthening standards on data collection, processing and QA
The World Bank Climate Change Knowledge Portal applies WMO and IPCC standards to ensure data comparability and usability across sectors.	2.2.2 Strengthening standards on data collection, processing and QA
Zanzibar uses the Framework for the Development of Environmental Statistics (FDES) to assess and improve its environmental data quality.	2.2.2 Strengthening standards on data collection, processing and QA
ODIS has compiled manuals, guides and best practices for ocean data in a repository, providing a model for similar actions in other domains.	2.2.2 Strengthening standards on data collection, processing and QA
EOSC provides a federated framework for open scientific data sharing, offering tools, standards and best practices that support provenance tracking and interoperability.	2.2.3 Ensuring transparency and provenance tracking
International reporting frameworks such as the ETF ensure that climate data are regularly verified, openly available and structured according to clear methodological guidelines.	2.2.4 Preserving confidence and trust in environmental data
The Dutch CO_2 Emission Factors Database provides standardized emissions data to ensure consistent corporate GHG calculations	2.2.5 Integrating businesses into data governance
UNECE and SPREP priority indicator sets respond to needs for policymaking and environmental assessments.	2.2.5 Aligning data generation with decision-making needs
The US validates EO data rigorously and offers a structured approach to integrating it across different government agencies and policy domains.	2.2.5 Aligning data generation with decision-making needs
National initiatives such as New Zealand's Climate Data Programme and the US Global Change Research Programme drive coordination across government.	2.2.6 Responding to the need for integrated data and assessments
The World Bank's Livable Planet Observatory will facilitate global access to cross-sectoral datasets.	2.2.6 Responding to the need for integrated data and assessments
IPBES and IPCC provide successful models for synthesizing environmental, social and economic information into decision-making frameworks	2.2.6 Responding to the need for integrated data and assessments
Japan's ecosystem assessments synthesize available evidence, leveraging existing platforms	2.2.6 Responding to the need for integrated data and assessments

6 Pillar III: Interoperability

6.1 Scope and vision

The interoperability pillar addresses the measures needed to ensure the distributed components of the environmental data ecosystem work together (i.e. interoperate) with minimal overheads. At its core, interoperability is enabled by the combined use of common data formats, semantic standards and data models, which together define how environmental information is structured, related and exchanged across systems. Components should be able to discover, access, process, and understand one another's data without the need to perform conversions or transformations, often losing information and incurring significant costs (financial and environmental, due to increased energy use) in the process.

Key measures include:

- harmonizing standards for data formats, metadata, APIs and cloud platforms;
- aligning semantic terminologies, definitions and classifications;
- documenting data sharing policies;
- promoting open-source software and platforms;
- developing API infrastructure;
- using AI to improve interoperability.

Differences in quality assurance, which can hinder trust and comparability across datasets, are taken up in Pillar II. Issues relating to the lack of infrastructures and skills are addressed in Pillar V.

In the interoperability context, achieving UNEP's vision would imply that, in 2035, data flowing through the global environmental data ecosystem are discoverable, accessible and (re)usable with minimal processing. Diverse datasets can be integrated rapidly and at low-cost across platforms, domains and regions, fostering collaboration, innovation and informed decision-making. Using globally oriented, cross-domain interoperability standards, it also connects environmental data with social and economic information for holistic analysis.

6.2 Key challenges and potential responses

Harmonizing data formats, standards and semantics

Challenges

Technical challenges in data formats, metadata standards and semantic inconsistencies create major obstacles to data sharing, integration and large-scale environmental modeling of multiple variables and impacts. These barriers limit the ability to combine datasets from different sources, impeding efforts to track environmental change, assess risks and guide policy.

Fragmentated environmental data standards and licences: There exist multiple international standards and frameworks for environmental data, including those created by ISO, ITU, OGC, IETF and W3C. However, awareness of these different standards is often lacking and they are inconsistently applied by different stakeholders. Each environmental domain is led by different stakeholders and processes and there is no organization or mechanism ensuring interoperability across domains. Proprietary standards related to licensed software can in some cases hinder development of better data governance. Established organizational practices and acquired skills and knowledge can exacerbate lock ins.

Inconsistent data formats: Environmental data are generated in widely varying formats, often tailored to specific use cases, domains, institutions or regions. Many datasets require reformatting, cleaning and manual processing before they can be used for broader analyses, which increases costs, reduces efficiency and hinders collaboration. These challenges are exacerbated where formats require proprietary software. Many countries lack clear obligations and guidance for standardized data reporting in response to national and international obligations, leading to inconsistencies in how environmental data are structured, stored and shared.

Inconsistent metadata standards: The absence of metadata is an important constraint on data quality (see Section 2.3). Yet even when metadata are included, different environmental domains and organizations use contrasting metadata standards, making it difficult to align datasets. Without harmonized metadata frameworks, users struggle to assess data origins, accuracy and relevance, increasing risks of misinterpretation. In many cases, metadata are not developed in machine-readable formats, which hinders discovery by search engines and AI.

Semantic inconsistencies: Differences in terminology, taxonomies and ontologies prevent datasets from being effectively combined or compared. The same environmental feature may be classified differently across institutions and regions, leading to gaps, overlaps and contradictions. Vocabularies and classifications vary by country and organization, making it difficult to harmonize data in domains such as biodiversity, pollution and land-use. Many researchers lack guidance on selecting standardized ontologies, further fragmenting environmental data ecosystems and limiting discoverability, including by AI. The absence of clear documentation on terminology and acronyms also makes accessing and interpreting data unnecessarily difficult.

Responses

Achieving greater harmonization in data formats, standards and semantics requires a combination of technical standardization, community engagement and pragmatic solutions tailored to resource constraints.

Promoting open standards: As a general principle, it is essential that countries, international organizations and other stakeholders seek to adopt and promote open standards. Open standards are publicly available specifications for data formats, metadata and protocols that are developed through transparent, inclusive processes and are intended to promote interoperability and reuse. Not all open standards are free. The International Organization for Standardization (ISO), for example, is a non-profit organization and charges some fees to cover the costs of developing and maintaining its standards. Other open standards, like those from the Open Geospatial Consortium (OGC), the Organization for the

Advancement of Structured Information Standards (OASIS) or the World Wide Web Consortium (W3C), are freely available. Despite this variation, open standards play a critical role in enabling data to be combined across systems and sectors, avoiding vendor lock-in and ensuring long-term accessibility. Promoting their adoption is a strategic step toward building coherent, scalable and inclusive environmental data infrastructures. Governments and international bodies should lead by example by aligning national data systems with widely recognized open standards, supporting implementation in low-resource settings and investing in the capacity needed to apply them effectively.

Adopting internationally recognized data formats: Publishing data in open, standards-based formats endorsed by key bodies such as the Open Geospatial Consortium (OGC) and ISO is essential to enable seamless data integration and cross-domain interoperability. Widely used formats include GeoJSON for geospatial vector data, Cloud Optimized GeoTIFF (COG) for raster data, SpatioTemporal Asset Catalog (STAC) for cataloguing large datasets, and OData for structured access to tabular or relational data via APIs. While cloud-optimized formats like COG and STAC are well suited to cloud environments, simpler formats like CSV remain effective in resource-constrained settings. The US Federal Data Strategy offers a good example of a structured approach to enhancing data interoperability (US, 2020). UNEP could support uptake of such formats by developing technical guidance and best-practice examples tailored to low-resource settings. Such resources can serve as templates for implementation, and help build capacity in national agencies and research institutions.

Aligning and implementing metadata standards: Standardization of metadata frameworks would provide a vital foundation for bridging gaps within and between environmental domains. This includes wider adoption of commonly used metadata standards such as ISO 19115 and 19139, DCMI (Dublin Core Metadata Initiative), DCAT (Data Catalog Vocabulary), SDMX (Statistical Data and Metadata eXchange) and DDI-Lifecycle (Data Documentation Initiative Lifecycle). Implementing these standardized metadata frameworks enhances data discoverability, interoperability and reusability. They facilitate machine-to-machine communication and ensure that critical information, such as data source, production and update dates, access restrictions, methodologies, legal obligations and the context of data collection and management, is transparently documented. There would be substantial value in global efforts – engaging relevant international organizations, national agencies and standards bodies – to define and promote minimum metadata standards aligned with FAIR principles.

Box 6.1 UNEP Mediterranean Action Plan (UNEP-MAP)

The UNEP Mediterranean Action Plan achieves regional environmental data standardization through a structured data policy agreed upon by participating countries under the Barcelona Convention. UNEP-MAP has established metadata standards to enhance interoperability across both geographical and non-geographical datasets, ensuring consistency in environmental reporting. Its platform enables data sharing through country-level focal points, facilitating cross-border collaboration and informed policymaking. To support adoption, UNEP-MAP has also invested in training programs to ensure users understand how to apply standards effectively, improving both data usability and stakeholder engagement.

Defining minimum metadata standards: Global action to agree on minimum metadata standards that ensure that data are findable, accessible, interoperable and reusable (FAIR) and machine readable would improve traceability and data integration substantially. While the diverse priorities of stakeholders make it challenging to achieve consensus on standards, the work of international initiatives and communities such as the Global Earth Observation System of Systems (GEOSS), the Global Biodiversity Information Facility (GBIF) and Open Geospatial Consortium (OGC) provides an essential foundation for further steps towards alignment and minimum standards. Global action to agree on cross-domain metadata frameworks would further enhance integration efforts, with the WorldFair project's emerging Cross-Domain Interoperability Framework (CDIF) providing methodologies for aligning metadata standards across disciplines (Gregory et al., 2024).

Building on these efforts, UNEP could organize a process to develop and maintain a **curated reference compendium of key environmental data standards**, in collaboration with domain experts and relevant standards bodies such as ISO, OGC, and W3C. This compendium could map standards, vocabularies, ontologies and metadata frameworks by environmental domain (e.g. geospatial data, air quality, biodiversity, sustainable finance), linking them to specific data types, reporting obligations and decision-making use cases. Such a resource would support stakeholders in navigating the complex standards landscape, improve comparability and discoverability, and provide a trusted foundation for environmental data governance and integration. Models such as ELIXIR's Core Data Resources in the life sciences offer useful precedents for this approach, and work by ISO to map and categorize its environment-related standards provides a foundation to expand.

Improving semantic consistency: Adoption of domain-specific standardized vocabularies and ontologies is also essential for interoperability. Examples include GCMD Keywords for Earth science data, AGROVOC for agriculture and food systems, ECOLEX for environmental law and policy, GBIF taxonomies for biodiversity and LEO (Linked Environmental Ontology) for structured environmental data integration. CDIF has an important role in supporting semantic alignment across these diverse domains by providing structured frameworks that enable datasets from different disciplines to be linked and integrated effectively. Communities of researchers, practitioners and domain experts can play an important role in developing ontologies within specific domains.

Looking across domains, development of semantic mapping tools can link existing taxonomies, vocabularies and ontologies, reducing fragmentation and improving integration across disciplines. Such tools are crucial for enabling cross-domain environmental data analysis, ensuring that datasets on biodiversity, climate, pollution and land-use can be integrated into broader sustainability assessments.

Box 6.2 Initiatives supporting standardization of geospatial and environmental data

Efforts at international and national scales are advancing geospatial and environmental data standardization, offering valuable models for broader harmonization. For example:

- **UK Geospatial Data Standards Register** catalogues and promotes the use of consistent data standards across sectors, supporting integration, reuse and innovation.
- **UN Integrated Geospatial Information Framework (UN-IGIF)** provides strategic guidance for countries to strengthen geospatial data infrastructures and align with global standards.

- **OGC Standards Working Group on Geospatial Reporting Indicators** is developing standards to support indicator-based reporting, enabling consistent spatial representation of SDG and environmental metrics.
- **eCITES Toolkit** provides a standards-based digital framework for CITES permits and certificates, using international standards from UN/CEFACT and the World Customs Organization (WCO) to enable secure and interoperable exchange of cross-border permit data.

These efforts contribute to a growing ecosystem of geospatial and environmental data standards that can be leveraged and aligned through coordinated global initiatives.

Promoting workflow and documentation interoperability

Challenges

Ensuring that environmental data workflows are interoperable and reproducible is essential for integrating datasets across different institutions, regions and analytical frameworks. However, weak documentation, inconsistent metadata practices and a lack of linked data frameworks create major barriers to data exchange and reuse.

Workflow interoperability and reproducibility: Workflows often lack clear guidance on how they can be implemented in different settings, making it difficult for researchers and practitioners to apply existing methodologies to their own data. Many projects produce only a final report, often in PDF format. Underlying data may be unavailable or restricted behind a paywall, and may not be accompanied by detailed descriptions of models and workflows that would allow others to reproduce or adapt their analyses. This limits the scalability of environmental data analysis and complicates efforts to harmonize environmental assessments across different jurisdictions.

Weak documentation of data repositories and access protocols: Large-scale environmental datasets undergo periodic updates, modifications and methodological changes but these are not always documented or communicated effectively. Users often encounter difficulties in understanding how datasets have evolved over time, what methodological assumptions were used, or how best to integrate new data into existing workflows. In addition, access protocols (such as authentication requirements, licensing terms and data retrieval mechanisms) are often unclear, making it hard for users to obtain and use data. Insufficient documentation of sources, cataloguing and metadata further hinders discoverability and transparency, forcing users to spend additional time verifying and interpreting datasets before they can be used for analysis.

Absence of linked data frameworks: Environmental data is often stored in separate repositories, making it difficult to combine datasets from different domains, such as climate, biodiversity, pollution and socio-economic factors, into an integrated analysis. Because datasets are created for specific purposes, they often lack structured references that indicate potential relationships with other datasets. This makes cross-domain integration difficult, particularly when datasets use different terminologies, classifications or formats. Without mechanisms for systematically linking related data, researchers and decision-makers must rely on manual effort to identify, compare and align datasets.

Responses

Strengthening workflows and documentation can ensure that data can be efficiently reused across institutions and disciplines, while linked data approaches would enhance integration across environmental domains.

Enhancing workflow interoperability and reproducibility: Ensuring that environmental workflows are adaptable and reusable across different contexts requires clear documentation and standardization. Projects must shift towards publishing the entire workflow, including data inputs, methodologies, processing tools and outputs. This would greatly enhance transparency and scalability. Practical examples, such as the OGC Open Science Persistent Demonstrator, show how interoperable, reproducible workflows can be implemented across diverse institutions and platforms. The Demonstrator brings together services from ESA, NASA and others to support open science using shared protocols, persistent identifiers and cloud infrastructures. It emphasizes modularity, version control and reuse — making it easier for researchers to validate and adapt workflows across domains.

Discoverability tools can further help researchers and policymakers identify and apply validated processes. Platforms such as GitHub, WorkflowHub and Zenodo can facilitate collaboration by hosting open workflows and version-controlled documentation. To strengthen reuse and reduce duplication, a curated registry of validated workflows that is aligned with these platforms could help users find, evaluate and adapt well-established methodologies across environmental domains. Additionally, adopting workflow management standards like Common Workflow Language (CWL) and Workflow Description Language (WDL) can support consistency, ensuring that data processing pipelines are more FAIR-compliant. Establishing a global working group or community of practice on workflow interoperability, involving standards bodies, scientific institutions, national agencies and existing initiatives, could support alignment across methodologies, promote uptake of shared standards, and improve coordination across domains.

Strengthening metadata and version control for datasets: Ensuring comprehensive metadata and documentation at all stages of the data lifecycle is critical to ensure that users are aware of modifications, updates and reformatting. Minimum metadata requirements should capture data sources, transformations, version history and quality indicators, following standards such as ISO 19115 for geospatial metadata. Clear version control practices using persistent digital object identifiers (DOIs) should be widely adopted so that users can track dataset modifications. Changes to APIs, repository structures or data access protocols also need to be recorded transparently. Logging updates in CHANGELOG files or release notes, hosting real-time documentation updates on GitHub and implementing automated user notifications (via email or in-platform alerts) can improve visibility and usability.

Establishing linked data frameworks for integrated environmental analysis: Adopting linked data principles using semantic web standards like RDF (Resource Description Framework), SPARQL and OWL (Web Ontology Language) enables datasets to be machine-readable and interlinked, facilitating deeper integration and automated data discovery. Semantic mapping tools can help link diverse taxonomies and ontologies, addressing inconsistencies in terminology and classifications across environmental datasets. Initiatives such as GO FAIR and W3C's Linked Open Data standards provide best practices for implementing linked data frameworks, making it easier to connect, search and integrate datasets. Platforms such as InforMEA, GBIF (for biodiversity) and ODIS (for ocean data) have begun adopting these approaches, particularly through the use of RDF and semantic technologies. However, further support is needed to mainstream linked data practices across contributors and domains, and to embed workflow transparency and semantic integration more systematically into existing infrastructures.

Box 6.3 DataCommons.org

DataCommons.org is an open-source project supported by Google that aggregates and links datasets from public sources such as Census, NOAA and the World Bank. Its goal is to make linked and queryable data more accessible for analysis and decision-making. It combines structured data from diverse sources into a unified knowledge graph and offer a query interface using technologies like SPARQL and supports tools like Jupyter Notebooks. It focuses on integrating publicly available datasets and enabling users to analyse them. Organizations can also spin up their own Data Commons instance so that they can maintain under their own licensing, governance and logins. The Data Commons has worked closely with the United Nations and others to support these instances, for example in the UN Data Commons for the SDGs (UN, 2025).

Enhancing machine-to-machine infrastructure

Challenges

Machine-to-machine interfaces (e.g. APIs, MQTT servers) are essential for enabling automated data exchange, real-time processing and seamless system integration. At present, many environmental data platforms either lack open APIs altogether or rely on inconsistent, fragmented approaches that limit accessibility and interoperability. These constraints create inefficiencies, increase manual workload and reduce the potential for real-time decision-making based on dynamic environmental data.

Absence of machine-to-machine interfaces across environmental data systems. Many databases and repositories still require manual downloads, limiting their ability to support automated workflows or integrate with live monitoring tools. The absence of M2M interfaces prevents systems from querying, exchanging and processing data automatically. This makes it difficult for researchers, policymakers and businesses to interact with real-time or regularly updated data and necessitates labour intensive and error-prone manual updates. It also leads to data silos and reduces the impetus behind harmonization of standards and formats..

Fragmentation of API frameworks: Different environmental data providers, including government agencies, research institutions and private-sector actors, use varying API formats, authentication mechanisms and protocols. This lack of standardization forces developers and data users to build custom solutions for each platform, increasing inefficiencies and limiting seamless cross-platform data sharing. Without commonly accepted open API frameworks, environmental data exchange is constrained, slowing progress toward integrated global environmental monitoring systems and analysis.

Responses

Addressing these limitations requires increased adoption of open standards for M2M interfaces, harmonizing API frameworks and collaboration between environmental data providers to improve interoperability and efficiency.

Expanding API adoption across environmental data platforms and data spaces: To increase adoption of APIs, governments and international organizations can mandate API development in publicly funded environmental data platforms or data spaces, and fund retrofitting of legacy databases with API functionalities to reduce reliance on manual downloads and outdated sharing mechanisms. Incorporating API-based data sharing into scientific research projects can further improve accessibility and cross-institutional collaboration. At the same time, it may be worth exploring increased use of scalable cloud-native spatial data infrastructures to reduce reliance on local servers and APIs and facilitate real-time data access. Governments and international organizations can also provide technical guidance and step-by-step templates to support countries in designing and deploying APIs, drawing on existing models such as the US Federal Data Strategy.

Using open and standardized API frameworks: Cross platform interoperability and data exchange can be enhanced by ensuring that platforms apply established open API standards (e.g. openEO API, Geospatial Data Cube API, OGC API Process and OGC API Records), use standardized data formats (e.g. GeoJSON, JSON-LD) and are aligned with FAIR data principles so that they are machine-readable, searchable and compatible across institutions and domains. Coordinated efforts to identify and promote a core set of widely accepted API standards, including protocols, tools, and documentation formats, would help align environmental data providers around best practices and reduce fragmentation.

Enhancing API discoverability and documentation: Indexing of APIs is vital for interoperability. Governments and multilateral organizations could establish centralized API indexing platforms, similar to NASA's API portal (NASA, 2025) where environmental data providers can register their APIs for open access. A global environmental API hub, aggregating APIs from governments, research institutions, businesses and NGOs, could serve as a shared discovery layer, improving transparency, usability and cross-sector integration. Requiring standardized API documentation using, for example, OpenAPI would further help ensure usability for developers, researchers and policymakers.

Integrating APIs into environmental monitoring, decision-making and action: As real-time data becomes increasingly central to environmental governance, greater use of APIs in national and regional monitoring frameworks can support more timely, evidence-based policy action.The private-sector can be better engaged by promoting open APIs that allow businesses to contribute and access environmental data for sustainability reporting, ESG assessments and impact evaluations.

Balancing harmonization and flexibility in interoperability protocols

Challenges

Efforts to standardize interoperability protocols (i.e. the rules and standards governing data formats and exchange, metadata, semantics, APIs and validation, which collectively determine interoperability) are important to ensure seamless environmental data exchange and integration. However, overly prescriptive interoperability requirements can be counter-productive if they hinder wide adoption and deter innovation.

Incoherent and overlapping standards: The environmental data ecosystem is fragmented by a proliferation of overlapping and inconsistent technical standards. Different institutions, domains and software platforms apply distinct methodologies and formats, complicating interoperability. For example, while some organizations rely on Google Earth Engine or Carto, others use Python-based tools or ESRI platforms, requiring time-consuming data conversions and manual transfers. The lack of standardized formats and cross-platform compatibility slows collaboration and creates technical bottlenecks. While stakeholders recognize the need for common interoperability standards, achieving alignment across diverse geospatial and environmental domains remains a challenge.

Overly prescriptive interoperability protocols: Interoperability protocols must strike a balance between harmonization and flexibility. In some cases, rigid and overly demanding standards hinder adoption, particularly for smaller organizations or developing countries with limited technical capacity. Experience implementing prescriptive frameworks, such as the EU's INSPIRE Directive, show that while ambitious standardization efforts can improve data consistency, their complexity can create implementation challenges. Evaluations of INSPIRE have found that the directive's intricate technical requirements have often been difficult to comply with, especially for resource-constrained organizations (EC, 2022; ODI, 2023).

Balancing standardization with innovation: While standardized protocols are necessary to facilitate interoperability, they should not stifle innovation or limit adaptability to local and domain-specific contexts. Many environmental sectors have well-established domain-specific frameworks and communities of practice that effectively manage data in their respective fields. Such communities can help align practices. But strict interoperability requirements that fail to account for these existing structures can disrupt effective workflows rather than improve them.

Responses

A successful approach to standardizing interoperability must strike a balance between harmonization and flexibility, allowing innovation and adaptation to local contexts.

Comprehensive action to harmonize interoperability protocols: Achieving interoperability across the global environmental data ecosystem requires coordination from businesses, governments and multilateral organizations. While sector-specific frameworks exist, establishing streamlined cross-domain standards can further data exchange. This work is as much about engaging in deliberations and building trust as about technical solutions. If entities such as Microsoft, Google, Carto and Mapbox could align on common format and standards, such as SpatioTemporal Asset Catalog (STAC), it would to be a major step forward. Tools like DCAT and Schema.org provide reference points for developing a shared framework, while CDIF offers a flexible format for structured data interchange across environmental domains. The US EPA and the European Environment Agency both have long experience working across numerous jurisdictions to gather and integrate date and offer useful insights into how national-scale interoperability can be improved. Multistakeholder dialogues and technical working groups could work to develop a shared vision and a roadmap for interoperability, aligned with broader digital governance initiatives, such as open government data frameworks.

Promoting a simple, flexible approach to standardization: To avoid the pitfalls seen in complex frameworks like the EU's INSPIRE Directive, a phased and modular approach to interoperability is needed, especially for organizations with limited technical capacity. Instead of imposing a universal standard, protocols should allow flexibility, enabling different communities to align while maintaining autonomy for innovation. A minimal but widely accepted set of standards can ensure that interoperability evolves incrementally. Keeping the barriers to entry low, with minimal friction and complexity, is crucial for integrating more stakeholders into the data ecosystem. Capacity-building and targeted technical assistance are essential to help low-resource countries transition toward interoperable data ecosystems. Providing training, modular toolkits, and direct support for implementation can help these actors adopt flexible standards without overburdening existing systems.

Supporting federated data architectures and semantic alignment: Decentralized and federated data-sharing models, where local entities retain control over data while adhering to core global standards, can provide a balance between harmonization and adaptability. Federated, modular data systems allow different actors, including countries, agencies, research institutions and the private sector, to maintain control over their data while enabling structured interoperability through shared protocols and semantic alignment. To maximize interoperability and enable AI-based applications, environmental data should be published in machine-readable formats with semantic metadata, using standards such as RDF, OWL and JSON-LD. Structured and adaptable frameworks such as CDIF offer useful reference models for building such systems. Pilot projects testing linked open data principles, semantic alignment and machine-readable metadata standards can demonstrate real-world feasibility and help scale integrated environmental data applications

Building on existing standardization processes and activities: In seeking to align and consolidate interoperability protocols, governments and organizations should build on the activities of international bodies such as ISO and the Open Geospatial Consortium (OGC), which have strong associations with national standards institutions. Platforms such as InforMEA, which provides a harmonized metadata framework and shared governance across multilateral environmental agreements, also offer useful models for cross-institutional standardization.

Engaging local standards bodies can help drive local adoption of global standards, support capacity-building and improve regulatory alignment. Similarly, a pragmatic approach to increasing interoperability could start with developing formal data-sharing protocols across organizations and regions. Donor organizations and financial institutions can also serve as catalysts for interoperability by embedding data-sharing and governance requirements into funding conditions. The World Bank's implementation of environmental and social standards, which has influenced the practices of UN agencies and suppliers, demonstrates how donor-driven requirements can improve standardization. Regulatory policies that require data collection, such as due diligence laws, can also incentivize cooperation and interoperability.

Monitoring progress and identifying gaps: Regular assessment of progress in improving interoperability, including uptake of shared standards, reduction in fragmentation and alignment across domains, can help track where further investment or coordination is needed. These insights could inform periodic reviews by international organizations and treaty secretariats.

Navigating proprietary software and closed data ecosystems

Challenges

Cloud platforms and proprietary software often offer powerful resources for improving environmental data management, yet they also create challenges for interoperability, accessibility and long-term sustainability. These include risks of vendor lock-in, high costs and restrictions on collaboration that limit the flexibility of data users and impede the development of open, interoperable data ecosystems.

Reliance on proprietary software limits collaboration: Environmental data initiatives often require collaboration between UN agencies, national offices, public utilities, academic institutions and private-sector partners. However, widely used proprietary platforms such as ESRI, Apple, Tableau and Google Earth Engine (GEE) operate under commercial (or partially commercial) licensing models. This can create barriers to data sharing, as organizations can equip internal teams with proprietary tools but struggle to extend access to external collaborators who lack necessary licences. Open-source alternatives (e.g., QGIS, Open Data Cube) offer more flexibility but often lack the same level of institutional support and adoption.

Vendor lock-In and risks of closed data ecosystems: Increasing reliance on closed-source platforms, particularly cloud-based services, risks creating vendor lock-in, where organizations become dependent on a single provider. Google Earth Engine, for instance, has become an essential tool within the global environmental data ecosystem. Yet there are clear risks if organizations build long-term dependencies on platforms that may change terms of use, restrict data access or even discontinue services. The lack of publicly funded alternatives further limits options for governments and researchers.

Fragmentation and interoperability challenges in cloud platforms: Private-sector platforms have incentives to prioritize profitability and proprietary ecosystems over interoperability with open data standards. Many commercial providers lack motivation to adopt common data formats, APIs, or metadata standards, leading to fragmented and siloed data. Proprietary formats and protocols create technical barriers to integrating data across platforms, requiring costly and time-consuming conversions.

Responses

To ensure sustainable, interoperable data ecosystems, governments, international organizations and research institutions can promote open-source alternatives to proprietary platforms and take actions to mitigate vendor lock-in and strengthen cloud interoperability.

Mitigating vendor lock-in and ensuring long-term data access: Governments and funding agencies can support the development of publicly funded, open-source alternatives that provide essential environmental data processing capabilities without the risk of service discontinuation or restrictive licensing. NASA Earthdata provides a strong example by offering remote sensing data in open formats such as GeoTIFF and NetCDF, ensuring long-term accessibility. Institutions could also conduct periodic assessments of their reliance on proprietary platforms, tracking how dependencies evolve over time and identifying proactive measures to diversify their data infrastructure. Global dialogues convening governments, cloud providers and open-source communities could help mitigate risks of monopolization and fragmentation. Such dialogues could promote voluntary agreements to improve cross-platform data sharing, minimize restrictive licensing and ensure that critical environmental data services remain open, transparent and interoperable.

Promoting open-source software: Governments and international organizations can promote open-source software such as QGIS, Apache Superset and Open Data Cube, by actively funding their development and maintenance to ensure long-term sustainability. While open-source adoption is increasing, some projects fail due to lack of resources, making consistent funding mechanisms essential. This could involve pooled international funding, national-level investment, or public-private partnerships to maintain key open-source infrastructure. **In parallel, paid software that adheres to open standards can also play a valuable role by reducing vendor lock-in and supporting interoperability, even within proprietary environments.**

To enhance collaboration, governments can also make publicly funded environmental data processing tools open-source. For example, Canada has developed an inter-departmental Python script-sharing initiative to facilitate environmental data processing. Governments and multilateral organizations can also support open-source adoption by providing training, technical assistance, and migration support, particularly in low-capacity settings.

Box 6.4 Germany's Open CoDE initiative

Germany's Open CoDE initiative, launched in June 2022, is a publicly accessible open-source code repository that enhances transparency and collaboration across government agencies. Designed as a shared digital space, it allows public institutions to upload, share, and reuse code, facilitating the standardization and verification of data processing methods. While not exclusively dedicated to environmental data, the platform enables greater transparency in emissions inventory processing and other data-driven government initiatives by making source code and processing steps openly available.

Adopting best practices, such as the OGC Best Practice for EO Application Package, can help ensure that platforms are built with interoperability in mind while benefiting from existing community-driven developments. The European Open Science Cloud (EOSC) also provides a model for applying FAIR principles to cloud-based environmental data infrastructures.

Strengthening cloud interoperability and cross-platform integration: Ensuring that cloud-hosted environmental data remains accessible across different providers requires stronger adoption of interoperability frameworks. OGC-compliant services such as WMS (Web Map Service) and WFS (Web Feature Service) play an essential role, alongside cloud-native geospatial solutions such as SpatioTemporal Asset Catalog (STAC), Cloud Optimized GeoTIFF (COG) and openEO API. Advancing standardized API frameworks would further streamline cloud data access and ensure compatibility across providers, preventing data fragmentation. Governments could also consider establishing licensing conditions when public environmental data is monetized through proprietary applications (e.g., Apple or Google apps), ensuring transparency and public benefit in cases where public data influences consumer behavior.

Improving interoperability in ESG and product-level environmental disclosures

Challenges

Corporate sustainability reporting and product-level environmental disclosures are playing an increasingly central role in shaping investment decisions, guiding policy implementation, and supporting consumer choices. However, the systems that structure and manage these data remain highly fragmented. The lack of interoperability between ESG frameworks, public reporting systems, and product-level data infrastructures makes it difficult to generate a coherent picture of environmental performance across sectors and scales.

Fragmented and misaligned reporting frameworks: ESG disclosure systems remain fragmented across competing frameworks (e.g. GRI, CDP, ISSB, ESRS, TNFD and SBTN) that use differing definitions, metrics and reporting requirements, including on how materiality is assessed and which sustainability issues are prioritized. These definition and methodological inconsistencies, particularly around Scope 3 emissions and nature-related risks, hinder comparability, confuse stakeholders and weaken links to global environmental goals. Similar asymmetries affect sustainable finance initiatives, such as carbon credit markets and biodiversity credits, where variable data requirements and a lack of standardization undermine trust and limit scalability. Even where companies seek alignment with public goals like the SDGs or Paris Agreement, structural differences in indicators, classifications and data models often prevent effective integration with national and multilateral reporting systems.

Absence of harmonized product-level data standards: Product-level environmental information, such as carbon footprints, recyclability ratings and digital product information systems, is becoming central to sustainability claims, trade regulations, and consumer choices. However, there is currently no globally recognized framework for how such data should be structured, validated or exchanged. Life Cycle Assessment (LCA) methodologies, which underpin much of this information, vary significantly across sectors and regions, often relying on different system boundaries, emission factors and assumptions. In addition, LCA datasets are published using a range of incompatible documentation formats (e.g. ILCD, Ecospold) and data structures (e.g. XML, JSON), limiting interoperability across platforms and jurisdictions. This fragmentation undermines the comparability and credibility of product-level disclosures, increases compliance burdens for businesses, and impedes the integration of product data into regulatory or market systems. Compounding these issues is the lack of harmonized metadata and taxonomy standards, which make it impossible to link, aggregate or align private data with global frameworks. The design and alignment of industry classifications is especially important in this regard.

Limited coordination between corporate and public data systems: While many disclosure frameworks now encourage companies to align their targets with global environmental objectives, they rarely use the same indicators, data schemas or metadata conventions as official reporting systems, such as those for SDG tracking or MEAs. This disconnect makes it difficult to integrate corporate disclosures into government inventories or global assessments, reducing the usefulness of private-sector data for environmental monitoring and decision-making.

Responses

Improving interoperability in ESG and product-level environmental disclosures requires a coordinated, multi-level approach. Addressing fragmentation, technical barriers and misalignment with public systems will depend on the active engagement of governments, standard-setting bodies, businesses and international organizations. The goal is not to create a single universal standard, but to enable structured, comparable, and policy-relevant data flows across a diverse and rapidly evolving ecosystem.

Aligning ESG frameworks through international collaboration and standard-setting: Stronger coordination is needed across major sustainability disclosure frameworks, such as GRI, ISSB, CDP, TNFD and SBTN, to harmonize key metrics, particularly on Scope 3 emissions and nature-related risks. Existing work by the UNEP Finance Initiative (UNEP FI), including sector-level materiality mappings and support for unified guidance under the TNFD and Science Based Targets Initiative (SBTi), provides a valuable foundation.

Improving semantic and structural alignment between corporate and public data systems: Developing shared taxonomies, metadata protocols and classification systems (particularly industry classifications) can enable corporate disclosures to feed into national inventories, SDG tracking and MEA reporting. Governments and standard-setting bodies can support alignment through common data infrastructures and technical guidance. Voluntary tools like the UNEP FI Impact Protocol can complement regulatory efforts by helping institutions align disclosures with global environmental goals. Similarly, the UNTP Sustainability Vocabulary Catalog provides a mechanism for voluntary schemes to publish unambiguous criteria and to align to harmonized taxonomies.

Establishing product-level data standards and baselines: Addressing fragmentation in product-level environmental disclosures requires globally interoperable standards and agreement on baseline methodologies. A priority is to define core data categories for Digital Product Information Systems that support consistency, comparability and integration across supply chains, and aligning LCA practices across sectors. Ongoing work under the UN Transparency Protocol (UNTP), UNEP's Life Cycle Initiative (LCI) and the Global Framework for Digital Product Information Systems offers a foundation for this effort. These initiatives aim to reduce misalignment among national and regional requirements through shared vocabularies, open-source architectures, and guidance on lifecycle-based impact assessment. Establishing common reporting baselines, similar to the Codex Planetarius in the food and agriculture domain, can enable credible and science-based product claims, facilitating trade and compliance. Together, these frameworks provide a practical pathway to improve the traceability, reliability and usability of product-level data in both regulatory and market contexts.

Facilitating access and interoperability of LCA data: Robust product assessments depend not only on standardized rules but also on accessible and interoperable LCA data infrastructure. Several countries are investing in national, open-access LCA databases to lower barriers to adoption and improve data quality. UNEP's Global LCA Data Access network (GLAD), launched in 2020, serves as the largest non-commercial directory of LCA datasets, linking independent data providers worldwide. Through GLAD, participating organizations agree on shared standards, such as flow nomenclature and metadata descriptors, to improve interoperability across tools and jurisdictions. These efforts help ensure that environmental data can be effectively reused, compared, and scaled in both private-sector applications and regulatory systems.

Leveraging AI to improve interoperability

Challenges

AI has the potential to significantly enhance data interoperability by automating metadata generation, aligning data schemas and improving quality assurance. But its potential is not yet widely understood or realized, in part because insufficient environmental data is machine readable.

Limited awareness and institutional readiness: AI has the potential to significantly enhance data interoperability by automating metadata generation, aligning data schemas and improving quality assurance. However, many organizations lack awareness of these capabilities (Tangi et al., 2023). Additionally, interoperability is often a secondary priority for many data producers, limiting investment in AI-driven solutions that could streamline cross-platform data integration. At present, many public sector datasets are not AI-ready due to inconsistent documentation, missing metadata and unstructured formats, making automated data alignment difficult.

Issues with standards and licensing hinder data readiness: There is a lack of standards on environmental data for readiness for AI, digital twin applications and Digital Product Information Systems, including basic standards on machine readability for AI applications. In addition, the advantages and disadvantages of different licence regimes are often difficult to understand and choosing the wrong licence can reduce the availability of environmental data for further analysis and ingestion by AI.

Technical and financial barriers: Even when organizations recognize AI's role in improving interoperability, implementation is hindered by resource constraints. AI-driven data integration requires specialized expertise in machine learning, data science and metadata management, which many governments and research institutions lack. There is a widespread skills gap in AI and data governance, making it difficult to scale AI interoperability initiatives. Additionally, budget limitations prevent public institutions from investing in the development and long-term maintenance of AI-enhanced interoperability solutions, leading to a reliance on external funding and short-term pilot projects rather than sustainable implementation.

Legal, ethical and standardization challenges: The integration of AI into environmental data systems must address regulatory and ethical considerations, particularly in relation to data transparency, accountability and privacy. Legal uncertainties and compliance requirements around AI-generated data complicate its adoption (Tangi et al., 2023). The lack of globally agreed frameworks for AI-generated metadata and schema alignment further slows progress, reinforcing inconsistencies in environmental data governance.

Responses

AI can significantly streamline metadata generation, schema alignment and data quality assurance, but its integration requires targeted investments, institutional readiness and standardized frameworks.

Enhancing awareness and institutional readiness: To build needed institutional capacity, governments, research institutions and international organizations should integrate AI for interoperability into national digital strategies and environmental data policies. This includes efforts to raise awareness among policymakers and IT professionals about how AI can streamline data integration and metadata generation. AI literacy will be increasingly important in public-sector data governance. At the same time, governments and funding agencies could require that new environmental data initiatives include AI-driven metadata automation and schema alignment as core components of their workflows. Multistakeholder partnerships between AI developers, governments and research institutions can also accelerate the deployment of AI-driven interoperability solutions, helping bridge technical gaps and enabling the co-development of AI data integration tools (Tangi et al., 2023).

Box 6.5 Frontiers FAIR2: AI-enhanced metadata and semantic alignment

Initiatives such as Frontiers FAIR[2] demonstrate how AI can be used to generate metadata that is not only FAIR (Findable, Accessible, Interoperable, Reusable) but also aligned with linked data principles and structured for reproducible environmental analysis. These approaches show the potential of AI to go beyond automation and actively enhance semantic alignment across datasets.

Addressing technical and financial barriers: Governments and international bodies can help ensure that environmental data are structured, well-documented and machine-readable by establishing minimum metadata and documentation requirements to enhance the AI-readiness of public-sector datasets. Public institutions and research organizations should expand training programmes in AI, machine learning and metadata management to address expertise shortages. AI capacity-building should be integrated into digital skills initiatives, particularly in under-resourced regions.

Governments and funding agencies could also allocate dedicated resources for AI-enhanced data integration, moving beyond short-term projects towards sustainable, long-term implementation. This could include supporting the creation of open-source AI tools for metadata alignment, schema mapping and interoperability standardization.

Investing in authoritative and sustainable ontologies: To support AI-driven metadata generation, schema alignment and semantic integration, the environmental data community must invest in the development and maintenance of standardized, authoritative and sustainable ontologies and taxonomies. These shared vocabularies provide the semantic structure that allows AI systems to interpret, align and integrate data across domains. They are essential for making datasets AI-ready, ensuring that data is not only machine-readable but also machine-understandable. Ontologies should be openly accessible, versioned and governed through participatory processes to ensure long-term sustainability, cross-domain applicability and trustworthiness.

Strengthening legal, ethical and standardization frameworks: The absence of clear governance frameworks for AI-generated metadata creates inconsistencies in environmental data governance. Governments should work with international standard-setting bodies (e.g., ISO, OGC, WMO) to establish guidelines ensuring AI-driven metadata follows best practices. AI-generated metadata and schema alignments should be explainable, auditable, designed to prevent biases and in environmental data interpretation. Governments should ensure that AI applications for interoperability comply with existing global frameworks such as FAIR, CARE and TRUST.

Fostering shared learning and governance: To scale AI for environmental data interoperability, it is essential to promote shared learning, practical guidance and collaborative governance. Governments, international organizations and research institutions would benefit from toolkits that include AI-readiness self-assessments, implementation roadmaps and real-world case studies, helping them plan and evaluate integration strategies. In parallel, a global repository of best practices, drawing on successful examples from agencies such as NASA, the European Commission and national pilot projects, can accelerate the diffusion of AI-driven solutions. Establishing communities of practice and open collaboration platforms will ensure that AI enhances, rather than fragments, the global environmental data ecosystem.

6.3 Summary of key responses

Table 6.1 summarizes the key actions proposed under each of the seven thematic areas addressed under Pillar III, spanning both national and international levels.

Table 6.1 Summary of key actions to enhance data quality and transparency

Focus area	Key actions
Harmonizing data formats, standards and semantics	• Define requirements for (meta)data formats, semantics and other standards to be fit for purpose, and work with standards organizations to update or extend existing standards accordingly, avoiding unnecessary creation of new ones. • Promote the adoption of open standards (e.g. from ISO, OASIS, OGC, UN/CEFACT, W3C) to support long-term interoperability and transparency, and avoid lock-in to specific vendors or systems. • Use open, standards-based and cross-domain data formats like JSON-LD, GeoJSON, GeoTIFF/COG, Parquet and ODatato ensure integration across domains. • Implement widely understood metadata standards (e.g. ISO 19115, schema.org, DCAT) to improve data discoverability and reuse, and connect these to policy-oriented standards (e.g. SDMX). • Support semantic clarity and interoperability by implementing high quality domain-specific and cross-domain semantic resources (e.g. vocabularies, ontologies), such as AGROVOC, Darwin Core, Environment Ontology, GEMET, the GCMD (Global Change Master Directory) and LEO (Law and Environment Ontology). • Engage the operators of key semantic resources and create officially recognized and reliable maps between them to support high-quality conversions/mediation and data commons platforms. • Promote the use of linked (open) data formats (e.g. RDF, OWL) to enhance transparency, observability and machine-actionability, and promote cross-domain integration through alignment with semantic web practices. • Promote the development and adoption of standard data models (e.g. ISO 19109, OGC Features and Geometries) to structure environmental data consistently across systems and domains.

Promoting workflow interoperability, documentation and linked data	• Require documentation of complete data workflows (inputs, tools, processing, outputs) to support reproducibility, provenance tracking, trust and reuse. • Promote open workflow platforms and standards (e.g. git-based development workflows, WorkflowHub, CWL, WDL) for transparency and collaboration. • Adopt version control practices and granular use of persistent identifiers (e.g. W3IDs and DOIs) to track dataset updates and changes.
Enhancing API infrastructure	• Expand the use of machine-to-machine interfaces (e.g. APIs, MQTT servers) across environmental platforms and fund upgrades for legacy systems. • Align machine-to-machine interface design with open standards (e.g. openEO, OpenAPI, OData) and ensure data are machine-readable and machine-actionable. • Support data mediation systems to serve data in the open formats and semantic markup needed by consumer systems, leveraging the semantic maps noted above. • Establish centralized indexing of environmental APIs and other machine-to-machine services / interfaces to improve discoverability and access, as done, for example, by the ODIS Catalogue of Sources (ODISCat). • Create monitoring solutions across the ecosystem to cross-verify that APIs are live and delivering high-quality, interoperable (meta)data. • Integrate regular use of machine-to-machine interfaces into national monitoring systems and private-sector tools to enable real-time, policy-relevant data use.
Balancing harmonization and flexibility in interoperability protocols	• Foster convergence around shared formats and protocols (e.g. STAC, Schema.org, DCAT), supported by stakeholder dialogue. • Support modular, phased implementation of standards to reduce complexity for low-capacity users and facilitate incremental adoption. • Encourage federated data architectures where local actors maintain control but align with shared semantics and standards. • Leverage existing institutions (e.g. ISO, OASIS, OGC, UN/CEFACT) and donor influence (e.g. funding conditions) to promote adoption. • Regularly monitor progress and identify remaining interoperability gaps across regions and domains.
Navigating proprietary software and closed data ecosystems	• Invest in open-source alternatives to mitigate vendor lock-in and ensure long-term access (e.g. QGIS, Open Data Cube), ensuring support for import/export of (meta)data using open, well formed and widely adopted standards. • Support national and global open-source repositories and code-sharing platforms (e.g. Zenodo, Open CoDE). • Adopt open, non-proprietary and globally oriented Analysis-ready, Cloud-optimized (ARCO) formats and standards (e.g. Apache Parquet, Zarr).

	• Promote cross-platform interoperability through open formats, common API frameworks and well-coordinated data mediation services. • Engage cloud providers to negotiate licensing and accessing conditions for public environmental data that is repackaged or monetized through proprietary applications and platforms (e.g. commercial weather or mapping services).
Improving interoperability in corporate ESG and product-level disclosures	• Support international coordination to align ESG reporting frameworks on key metrics (e.g. Scope 3, nature-related risks). • Harmonize corporate and public data systems through shared taxonomies, metadata protocols and data mediation services, including both structural and semantic conversion tools. • Develop minimum standards for product-level data and Digital Product Information Systems (e.g. lifecycle methods, open vocabularies). • Use initiatives like the UN Transparency Protocol and UNEP Life Cycle Initiative to guide alignment and data baselines. • Promote convergence of corporate sustainability disclosures with MEA, SDG and national reporting systems. • Use digital permanent identifiers to track products and associate them with other data linked with them.
Leveraging AI to improve interoperability	• Ensure digital strategies include components to increase awareness and literacy regarding the effective and ethical use of AI solutions. • Ensure that (meta)data conventions and standards support both machine learning (ML) and knowledge representation (KR) approaches in AI, using generic and open conventions that do not favour specific tools or providers. • Invest in training and capacity-building in AI skills, integrating them into digital literacy programmes, especially in under-resourced contexts. • Develop open-source AI tools designed to consume and produce data released in open, domain-neutral formats and semantic standards, and allocate long-term funding for scalable integration of AI into environmental workflows. • Create and sustain processes to continuously cross-validate, verify and audit AI solutions to ensure accuracy and robustness, assessing the transparency of any AI solution deployed. • Establish and maintain authoritative, sustainable ontologies and taxonomies to provide semantic structure for AI, and compatibility with knowledge graph technologies. • Develop and/or apply suitable ethical, legal and governance frameworks for AI-generated metadata (aligned with sound implementation of the FAIR, CARE and TRUST principles). • Create shared toolkits, clear guidelines and standard operating procedures to guide AI adoption, including readiness assessments and case studies.

6.4 Overview of best practices in Pillar III

Example	Section
Publishing data in widely used open, standards-based formats such as GeoJSON, GeoTIFF, STAC or CSV is essential to enable data integration and cross-domain interoperability.	3.2.1 Harmonizing data formats, standards and semantics
Adopting metadata standards such as ISO 19115 and 19139, DCMI, DCAT, SDMX and DDI-Lifecycle enables data discoverability, interoperability and reusability.	3.2.1 Harmonizing data formats, standards and semantics
WorldFAIR is developing the CDIF methodology for aligning metadata standards across disciplines, enabling consistent documentation, semantic integration and reusability.	3.2.1 Harmonizing data formats, standards and semantics
GBIF and OGC frameworks provide widely adopted standards for biodiversity and geospatial data, helping to align formats and protocols across domains.	3.2.1 Harmonizing data formats, standards and semantics
Standardized vocabularies and ontologies such as GCMD Keywords, AGROVOC, ECOLEX and GBIF taxonomies are essential for interoperability.	3.2.1 Harmonizing data formats, standards and semantics
UNEP-MAP drives standardization of data and metadata, facilitating cross-border collaboration and informed policymaking.	3.2.1 Harmonizing data formats, standards and semantics
The UK Geospatial Data Standards Register, UN-IGIF and the OGC Standards Working Group on Geospatial Reporting Indicators advance geospatial data standardization.	3.2.1 Harmonizing data formats, standards and semantics
The eCITES Toolkit enables standardized cross-border exchange of CITES permit data using international trade and customs data standards.	3.2.1 Harmonizing data formats, standards and semantics
InforMEA provides harmonized metadata and vocabularies across MEAs, supporting semantic alignment and machine-readable access to legal and policy data.	3.2.1 Harmonizing data formats, standards and semantics
OGC Open Science Persistent Demonstrator shows how Earth observation workflows from ESA, NASA and other sources can be made interoperable and reproducible.	3.2.2 Promoting workflow interoperability, documentation and linked data
DataCommons.org combines structured data from diverse sources into a unified knowledge graph and offers a query interface for analysis.	3.2.2 Promoting workflow interoperability, documentation and linked data
NASA's API portal enables environmental data providers to register their APIs for open access.	3.2.3 Enhancing API infrastructure
openEO API provides a common interface for accessing and processing geospatial data in the cloud, simplifying remote sensing workflows across platforms.	3.2.3 Enhancing API infrastructure

OGC's Environmental Data Retrieval (EDR) API standard offers "lightweight interfaces for straightforward access" to diverse environmental datasets lowering technical barriers.	3.2.3 Enhancing API infrastructure
Canada's interdepartmental Python script-sharing initiative facilitates environmental data processing across government.	3.2.5 Navigating proprietary software & closed data ecosystems
Germany's Open CoDE initiative allows public institutions to upload, share, and reuse code, facilitating the standardization and verification of data processing methods.	3.2.5 Navigating proprietary software & closed data ecosystems
The European Open Science Cloud (EOSC) provides a model for applying FAIR principles to cloud-based environmental data infrastructures.	3.2.5 Navigating proprietary software & closed data ecosystems
UNEP FI's Impact Protocol helps financial institutions align ESG disclosures with global environmental goals by providing harmonized metrics, classification systems and guidance.	3.2.6 Improving interoperability in ESG and product-level environmental disclosures
GLAD is the largest non-commercial directory of Life Cycle Assessment (LCA) datasets, providing a harmonized framework to link national and sectoral databases	3.2.6 Improving interoperability in ESG and product-level environmental disclosures

7 Pillar IV: Accessibility and affordability

7.1 Scope and vision

This pillar addresses measures to ensure that all stakeholders can access and afford the environmental data needed to support sustainable development. Key measures include:

- making data discoverable (e.g. through cataloguing and data formats);
- implementing open data principles and cost reduction measures;
- developing mechanisms to navigate legitimate concerns about sensitive data and security;
- increasing access to operational data held by the private sector;
- creating user-oriented data platforms and data spaces.

Issues relating to infrastructure and connectivity, which are essential for data access and affordability, are taken up under Pillar V on capacity-building.

In the accessibility and affordability context, achieving UNEP's vision would imply that, in 2035, the global environmental data ecosystem ensures equitable, sustainable and secure access to high-quality data and tools, while ensuring robust protections for data sovereignty and privacy. It is supported by affordable pricing structures, user-friendly platforms and strong collaboration across sectors. It prioritizes transparent licensing, ethical governance and rapid data sharing in emergencies, creating resilient infrastructures that empower stakeholders to use environmental data effectively for decision-making.

7.2 Key challenges and potential responses

Ensuring that repositories are findable and accessible

Challenges

Significant barriers prevent effective discovery and use of environmental data. Many datasets are difficult to locate, stored in inaccessible formats or scattered across fragmented repositories. Without systematic approaches to cataloging and integration, critical environmental information remains underutilized.

Difficulty finding existing data: Researchers, policymakers, businesses and NGOs struggle to identify what data exist, where they are stored and how to obtain them. The lack of comprehensive and up-to-date cataloguing of available datasets makes discovery a slow and inefficient process, often making users reliant on ad hoc searches and personal networks.

Inaccessible repositories and formats: Many datasets are still stored on local computers, in paper archives or in formats that hinder usability, such as PDFs. This not only makes retrieval difficult but also increases the risk of data loss over time. In some regions, particularly in developing countries, paper records continue to be a primary source of environmental information. Large databases with millions of records also go underutilized due to technical barriers that make them difficult to access. ESG data are frequently locked in closed or non-machine-readable formats, such as PDF reports or proprietary paywalled databases, which limits interoperability and prevents broader reuse in policymaking and public accountability efforts.

Fragmentation and siloed storage of environmental data: Instead of being consolidated in interoperable repositories, data are scattered across numerous platforms, institutions and regional initiatives. Public projects and MRV processes frequently generate significant environmental data during due diligence processes, yet these datasets are not included within open repositories. This lack of coordination hinders data integration and comparison, limiting potential impact. Governments and organizations often compound the problem by failing to allocate sufficient resources for systematic data storage and maintenance, preventing long-term accessibility.

Risk of data loss and degradation: Issues such as hardware failures, technological obsolescence and loss of data integrity due to unverified alterations can threaten the long-term accessibility and reliability of historical datasets. Additionally, unstable funding jeopardizes the sustainability of critical repositories and interoperability issues make it difficult to ensure seamless access across platforms and institutions.

Responses

Addressing the problems with discovery and access requires coordinated efforts to improve cataloging systems, modernize data formats and enhance interoperability between platforms.

Strengthening data discovery and cataloging systems: Encouraging organizations to index their datasets in open global data repositories such as ODIS and OpenAIRE can enhance discoverability, allowing users to quickly locate relevant datasets. There is also a need to develop regularly updated national and international environmental data catalogues that provide up-to-date information on available datasets, their locations and access conditions. Ensuring that catalogues adhere to employ standards such as DCAT can ensure that datasets are well-described and easily searchable. Using harmonized cataloging frameworks, such as SpatioTemporal Asset Catalogs (STAC), can further improve interoperability, particularly for geospatial data.

Metadata databases could serve as showcases of available data, enabling users to assess dataset relevance before requesting access, thereby improving efficiency. Federated catalogues that enable cross-platform metadata discovery without centralizing ownership offer a scalable approach for linking fragmented environmental data systems. National models offer practical examples of how metadata integration can work in decentralized systems. For example, Germany's Geoportal.de metadata platform consolidates over 40 sub-national data sources,. At the international scale, Switzerland has developed proposals for a global metadata platform to enhance data discoverability and transparency (Dalton, 2024).

Improving accessibility of data repositories and archives: Beyond cataloging, improving accessibility requires digitizing and modernizing legacy environmental data so that paper archives, scanned reports and inaccessible formats (e.g. PDFs) are transitioned into machine-readable, interoperable formats such as CSV, JSON and NetCDF. To maximize usability, publicly funded environmental data should be stored in open-access repositories and made available in non-proprietary, accessible formats. Initiatives like NASA Earthdata and OCHA's Humanitarian Data Exchange (HDX) exemplify best practices in ensuring discoverability and usability, compiling datasets that inform decision-making on environmental change and humanitarian crises. Implementation of open APIs can further facilitate real-time data access, integration and automated retrieval, reducing reliance on inefficient manual downloads. International efforts to monitor the formats, access conditions and structural quality of environmental data repositories on a regular basis can support continuous improvement

Promote open, machine-readable reporting formats and ESG data portals: Governments can require that ESG and product-level disclosures be submitted in structured, machine-readable formats (e.g. XML, JSON, RDF) using standardized vocabularies. Public data portals, including regulatory databases and sustainability registries, should adopt open APIs and avoid PDF-based or paywalled systems. The European Single Access Point (ESAP) provides a leading model for ESG data accessibility, offering centralized, searchable access to sustainability-related corporate information across the EU in machine-readable formats, supporting both transparency and interoperability.

Developing regional data repositories: Investing in regional environmental data repositories can harmonize and integrate data from diverse sources, providing the foundation for integrated assessment processes and evidence-based policymaking. Long-term funding for repository maintenance is also critical to ensuring the sustainability of open data systems, preventing reliance on short-term project-based funding cycles. For example, the INFORM project collates datasets from 14 Pacific Island countries, promoting a continual flow of information rather than project-bounded data collection and offering a tool that new projects can leverage instead of building separate, duplicative portals. National or regional strategies for repository development should prioritize long-term funding, technical standards alignment and coordinated data contribution requirements, particularly for publicly funded environmental data. Public projects generating environmental data, such as MRV systems and environmental impact assessments, could be required to deposit datasets into accessible, interoperable repositories to prevent valuable data from being lost or underutilized.

Developing long-term preservation strategies for environmental data repositories: Preservation strategies can help ensure that historical datasets remain accessible for future research, policy development and trend analysis. With the rapid evolution of data storage technologies, cloud-based and decentralized archiving models, such as federated data storage and blockchain-based integrity checks, can help safeguard datasets from loss or manipulation. Sustainable funding mechanisms are also important for maintaining critical environmental databases.

Reducing cost barriers to data access

Challenges

Costs significantly limit environmental data access and use, particularly for low-income countries. These barriers relate to both data acquisition and the financial burden of storage and management, disproportionately impacting resource-constrained organizations and regions.

High costs of accessing proprietary data: Many critical datasets, such as high-resolution satellite imagery and specialized environmental databases, are commercial. This restricts their use by researchers, NGOs and lower-income governments that cannot afford expensive data licenses. Generating and maintaining LCA datasets is also costly and the vast majority of LCA data available are only available commercially for a fee. Academic paywalls further restrict access, as research institutions can prioritize publications in proprietary journals over open dissemination. Meanwhile, many governments lack regulatory frameworks that mandate open access to publicly funded data, further limiting data availability.

High costs of data storage and management passed on to users: Managing and maintaining large volumes of information is costly. Running open data platforms requires substantial financial and technical resources, often creating dependencies on major technology providers for in-kind cloud storage and processing. The sheer scale of spatial data, remote sensing imagery and real-time monitoring systems places financial strain on governments and institutions who must cover expenses related to data storage, hosting and processing, especially in low-income countries. These costs can discourage organizations from freely sharing data, especially when managing large datasets with high computational demands.

Tensions between the desire for open access and the need to cover costs: The financial burden of storing and managing data means that many providers opt for paywalls or restricted access to offset their expenses, further limiting interoperability and data access. This creates accessibility gaps for researchers and decision-makers. Barriers can mean that relevant data are excluded from global modeling efforts simply because researchers cannot access them. Despite growing recognition that environmental data are public goods, there remains a lack of tested, replicable business models to sustainably finance their provision. This limits the ability of public institutions to maintain digital public goods and makes it difficult to establish equitable cost-sharing arrangements with the private sector. Without long-term financial models that fairly distribute costs and rewards, especially for large-scale data platforms and infrastructure, efforts to improve accessibility risk remaining fragmented and underfunded.

Responses

Expanding open access to publicly funded data: Governments and international organizations should adopt policies that recognize environmental data as a global public good, ensuring broad access to non-sensitive datasets. UNESCO's Recommendation on Open Science provides an international framework for open science policies and practices, setting out a range of key principles, including open access, open data, open-source software, open infrastructures, open evaluation, open educational resources and open engagement with society.

National and international policies could mandate open access to publicly funded environmental data, including information from satellite programmes, environmental monitoring stations and climate models. The 2022 White House memorandum from the Office of Science and Technology Policy (OSTP) exemplifies this approach, requiring that all federally funded research, including datasets, be made publicly accessible without embargo by 2025. Expanding similar policies globally would help democratize data access. Research institutions and funding agencies can also reduce academic paywalls by requiring that publicly funded environmental research data and findings be published in open-access journals or repositories, promoting transparency and wider usability. Agreeing on a shared global definition for "open data" would help advance these actions. For example, the World Bank's position is that data is not open if users are required to register before gaining access.

Box 7.1 Mobile applications for agroclimatic information in El Salvador

El Salvador's SIAM-MAG and Siembra IA apps leverage climate data from the Ministry of the Environment, processed at the Ministry of Agriculture, and then distributed to farmers via messaging services and agroclimatic tables. These platforms ensure that climate information is not just available but also usable in agricultural decision-making. Beyond accessibility, El Salvador is also testing new data-sharing models, compiling and processing remotely sensed environmental data with AI in order to make it transparent and accessible for the public. It is also experimenting with monetizing weather-related datasets, balancing open data principles with sustainable funding mechanisms.

Creating incentives for data sharing: To encourage countries to adopt open data policies, governments and international organizations could develop incentive-based mechanisms that provide financial, technical and infrastructural support in exchange for greater data openness. This could include granting access to datasets for countries that implement open data frameworks; providing capacity-building programmes to support data-sharing best practices and improve data governance; and financial support for digital infrastructure, ensuring that lower-income countries have the storage and processing capacity to maintain and share datasets effectively. World Bank initiatives, which offer technical assistance and funding to countries that commit to open data policies, can serve as a model for such approaches.

Developing open data platforms: Investing in public platforms that support open standards and broad access is crucial for making high-quality environmental data widely available. Successful models include the EU's Copernicus Programme and the USGS Landsat Program, which both provide free access to satellite imagery, the World Bank's Open Data Initiative, which makes development-related environmental datasets freely available, and the Livable Planet Explorer and GBIF, which provide API-driven access to environmental datasets. While full centralization of environmental data is likely to be costly and impractical, a federated environmental data utility, which offers centralized services on top of decentralized data repositories, offers a feasible alternative.

Box 7.2 Development Data Partnership

The Development Data Partnership (https://datapartnership.org) brings together 11 international organizations and nearly 30 companies to facilitate data collaboration. The Partnership has created the legal foundation, including templated master data license agreements, to access third-party data from various companies (e.g., Google, Planet, Meta). Today, it supports over 400 projects across its member organizations. Furthermore, the Partnership is working on making methodologies and code repositories available so that others, including client countries and other organizations, can leverage alternative data.

Increase investment in national and regional data infrastructures: Governments and international organizations could support the development of affordable, scalable data storage and processing infrastructures in developing countries, reducing dependency on commercial cloud providers. Regional data hubs, such as the INFORM project in the Pacific, can further help mitigate storage costs while supporting long-term data access.

Creating affordable and sustainable business models for data access: Governments and multilateral institutions can explore and pilot new ways to offset the costs of open-access data while ensuring affordability. This could involve, for example: tiered data access models where real-time or high-resolution data are freely available for research and policymaking but value-added services require payment; public-private partnerships where businesses contribute funding or infrastructure in exchange for shared access to open datasets; revenue-sharing models where businesses that monetize public data contribute a portion of their earnings toward maintaining open-access repositories; or negotiating licensing agreements that allow for free or reduced-cost access to privately held datasets for research or disaster response.

At the global scale, UNEP and its partners could explore options for developing a sustainably financed Global Environmental Data Utility that compensates or subsidizes data providers for making their datasets freely or affordably available to developing regions under a unified policy framework.

Box 7.3 OARE (Online Access to Research in the Environment)

OARE is a UNEP-led initiative, in partnership with Yale University, that provides researchers, educators and policymakers in over 120 low- and middle-income countries with free or low-cost access to more than 13,000 peer-reviewed journals, e-books and other scientific publications in the environmental sciences. It is one of five programmes under the broader Research4Life partnership, aimed at bridging the knowledge divide by enabling equitable access to scientific research. OARE supports informed decision-making, capacity-building and the integration of high-quality environmental evidence into national policies and assessments. As such, it serves as a model for expanding open access to authoritative data and knowledge products in support of sustainable development and environmental governance.

Balancing access against concerns about strategic and sensitive data

Challenges

Privacy concerns, political sensitivities and bureaucratic hurdles all hinder data access. While transparency is essential for informed decision-making, there are legitimate concerns about how certain data is used, who has access to it and what unintended consequences may arise.

Data sensitivity and national security concerns: Governments rightly restrict access to environmental data when it is deemed sensitive or strategic. Data related to national security, critical environmental infrastructure (e.g. energy / water) tracking of endangered species or Indigenous territories is often protected to prevent exploitation or harm. Additionally, in some cases, environmental data has implications for geopolitical tensions or conflict zones, such as monitoring the environmental impacts of war, displacement or extreme weather events in politically unstable regions. Legal frameworks, such as the Aarhus Convention, provide guidance on restrictions in cases where disclosure may threaten public safety, intellectual property, or national interests.

Concerns about misinterpretation and institutional criticism: Public institutions sometimes hesitate to release data due to concerns about misinterpretation, misinformation, legal action or criticism of their own performance. Officials argue that data without proper contextualization or certification could be misused or misunderstood, leading to inaccurate conclusions or reputational risks for governments and agencies. In some cases, this has led to a preference for publishing environmental reports in static formats like PDFs, rather than making raw data available in more usable formats such as CSV files. This can reduce transparency and hinder scientific and civil society engagement in environmental monitoring and policymaking. Unnecessary restrictions can sometimes stay in place simply due to institutional inertia.

Bureaucratic and legal barriers to data access: Even when environmental data exist, government actors can sometimes use their control over data as a means to exert power. Bureaucratic processes and legal restrictions can also make access difficult, particularly for non-governmental stakeholders. In some cases, sensitive data that could be released after embargo periods remains restricted. Data requests linked to freedom of information legislation often require lengthy approval processes, extensive documentation or detailed plans for data usage, creating administrative burdens. Many public agencies also manage datasets from multiple sources but face uncertainty about licensing frameworks, making it difficult to enable responsible and open access while maintaining necessary protections.

Responses

Striking a balance between transparency and protection requires clearer national and international policies and frameworks, as well as technical safeguards that allow sensitive data to be used effectively without compromising security, privacy or sovereignty.

Facilitating uptake of open data licences: Adopting standardized, open licensing frameworks, like Creative Commons (CC) or MIT licenses, can facilitate data sharing and reuse across sectors and regions. For example, GBIF has facilitated many projects and conservation initiatives, using standard open licenses (CC0, CC-BY, CC BY-NC) to share biodiversity data globally. But public agencies managing multi-source datasets also need clear guidance clarifying which datasets can be made openly accessible and which require restrictions due to legal, ethical or privacy concerns. Developing decision trees can help individuals in organizations in deciding which licence to apply and if non-commercial use restrictions are needed. Developing guidelines and decision-support tool, such as licensing decision trees, recommended licensing models, and examples of non-commercial or restricted-use agreements, can help institutions determine the appropriate licensing terms based on the sensitivity and intended use of data.

Reducing bureaucratic barriers: Governments can reduce bureaucratic barriers that delay legitimate access to environmental data by digitizing and standardizing approvals processes. API-based authentication can enable instant access for authorized users, reducing the need for lengthy manual approvals while maintaining security and data governance. In instances where access is restricted, it is important to ensure transparency about what data exist. For example, under Aarhus Convention rules, governments must disclose when data exist even if they are restricted, ensuring transparency without revealing confidential details.

Creating classification frameworks to facilitate data sharing: Developing and implementing frameworks that differentiate open access data from restricted or confidential data can enable responsible data sharing while protecting sensitive information. For example, the Aarhus Convention defines a set of criteria that justify restrictions on access to environmental data. Classification frameworks can also provide the basis for implementing tiered data access models, which ensure that non-sensitive environmental data are freely available, while access to sensitive data (e.g. relating to the location of endangered species, Indigenous lands or national security-related information) is more constrained. For example, it could be fully accessible for certain public officials but only available in summary or redacted form for the general public. Developing guidance materials, such as sample classification schemes, tiered access protocols and structured decision flows, can support consistent application of these frameworks across institutions.

Negotiating protocols to international agreements for sharing sensitive data: Legal agreements can foster trust facilitate and data sharing between countries by directly addressing issues of privacy, unauthorized use and sovereignty. For example, the Nagoya Protocol to the Convention on Biological Diversity provides a model for regulating the sharing of genetic resources and associated data while ensuring that participating countries maintain sovereignty. Technical working groups that include stakeholders from governments, Indigenous communities, scientific bodies and frameworks such as the Aarhus Convention can help align national classification systems and licensing approaches across jurisdictions. Efforts to align national classification systems can also help ensure that protections do not unnecessarily hinder cross-border data exchange.

Finding technical solutions for secure and responsible data sharing: Adopting technical solutions can allow sensitive environmental data to be used effectively without compromising privacy or security. At the international level, this could mean developing federated data-sharing frameworks that enable local data sovereignty while allowing integration into global environmental data platforms. For example, the EU Satellite Centre (SATCEN) enables sensitive geospatial data to be used securely in government and security applications, while maintaining strict governance over access. Decentralized trust mechanisms such as distributed ledgers (e.g., blockchain-based registries) can also enhance data integrity and traceability, reducing reliance on a single authority. Privacy-preserving AI techniques, such as federated learning, can also enable cross-institutional data analysis without transferring raw datasets across borders.

Trust federations such as the European Open Science Cloud and GAIA-X can also play a valuable role by establishing secure networks where participating organizations can share sensitive data under mutual trust agreements within a federated data ecosystem. These federations use standardized authentication protocols, such as SAML, OpenID Connect and OAuth, to ensure that data access is limited to verified users while maintaining interoperability across institutions. The European Commission's Joint Research Centre (JRC) has also demonstrated how federated learning can enable privacy-preserving AI applications that support public–private data reuse, including in the environmental domain. The JRC study *Technology Safeguards for the Re-Use of Confidential Data* (Bacco et al., 2025), outlines technical and governance models that allow machine learning on sensitive datasets without transferring raw data across borders.

Navigating commercial interests and cloud dependency

Private sector control over key environmental datasets and growing dependence on commercial cloud infrastructure create both opportunities and challenges for equitable and sustainable access to environmental data.

Challenges

Barriers to accessing corporate environmental data: A significant portion of environmental data is collected and held by private sector entities, including industries involved in transportation, finance, energy and agriculture. Businesses generate vast amounts of product-level and supply chain data that could support environmental monitoring, impact assessments and regulatory oversight, yet much of this information remains inaccessible to researchers and policymakers due to intellectual property concerns, commercial interests and a lack of data-sharing agreements. For example, financial institutions track money flows that could help combat illegal trade, while transport companies collect screening data that could aid in tracking invasive species. Regulatory agencies often struggle to assess cumulative environmental impacts because they lack access to the full range of data generated by businesses, including those monitoring regional development, biodiversity loss and pollution.

In some sectors, commodity traders and exchanges engage in trading arbitrage where bulk materials (e.g. base metals and concentrates) are traded multiple times between lifecycle processing steps. There is a strong commercial incentive to hide material source information because it can be used to infer trading margins. This lack of transparency creates barriers to end-to-end traceability and reduces the interoperability of sustainability data across product life cycles.

Lack of data availability also affects actors within the value chain itself. Companies often struggle to gather reliable environmental information from upstream suppliers, undermining the credibility of product-level disclosures such as Digital Product Information Systems and ESG metrics like Scope 3 emissions. In the tertiary sector, financial institutions face similar challenges in collecting downstream client data, especially when their primary environmental impacts are indirect. This limits their ability to assess financed emissions, support transition efforts, or disclose full value-chain impacts.

While regulations are increasingly being developed to improve the accessibility of product information, there remains limited clarity on which data will be made available to different types of stakeholders, (e.g. consumers, regulators and downstream users) and under what conditions. This lack of definition risks creating uneven access, uncertainty around data governance and barriers to effective implementation.

Data usage rights and monetization of public data: Restrictive or inconsistent licensing rules and unclear data usage rights hinder the sharing and reuse of environmental data. Additionally, big tech companies and private firms increasingly monetize public environmental data, using open datasets to create value-added commercial services or free services available on hardware that they sell. While this can improve data-driven applications, public authorities have limited mechanisms to recapture a share of this revenue to reinvest in data infrastructure and accessibility.

Cloud dependency risks and redundancy: Cloud-based platforms have transformed environmental data management, providing scalable storage, real-time processing and advanced analytical capabilities. However, growing reliance on a small number of commercial cloud providers raises concerns about data sovereignty, affordability and long-term accessibility. Environmental datasets may be vulnerable to access restrictions, changing pricing structures or service discontinuations dictated by private cloud providers. These risks disproportionately impact under-resourced organizations and developing countries, which may struggle to afford the costs of storing and processing large datasets on commercial cloud platforms.

Responses

Balancing commercial interests with public accessibility requires a combination of policy reforms, new technical solutions and innovative business models.

Incentivizing broader access to private-sector environmental data: Public policies and mechanisms can unlock privately held environmental data to support systemic analysis, while protecting business interests and privacy. Stronger open data laws and corporate disclosure and reporting requirements can help ensure that environmentally significant corporate data (e.g., pollution emissions, biodiversity impacts and supply chain risks) are made available for regulatory oversight and public benefit. International standards bodies and regulators can also help define what constitutes "material" and "non-sensitive" environmental data, guiding companies on what must be disclosed without violating trade secrets. The OECD Due Diligence Guidance for Responsible Business Conduct provides a useful reference for how corporate disclosures can support environmental and human rights risk assessments across supply chains. Voluntary corporate participation in global data-sharing initiatives, such as GBIF and SDG monitoring, can also be incentivized through public recognition of sustainability efforts or fiscal benefits.

Embedding safeguards for secure and responsible data sharing: Creating secure, aggregated data-sharing models that use anonymization, data encryption and aggregated reporting mechanisms can allow private-sector actors to share valuable insights without exposing proprietary or sensitive details. Implementing standardized data-sharing agreements and privacy-preserving architectures (e.g. tiered access rights, data anonymization or zero-knowledge proofs) can mitigate risks related to intellectual property or competitive harm. Initiatives like Gaia-X are developing common governance frameworks and trust architectures to enable secure, sovereign data sharing between public and private actors, offering models for how interoperability and control can be balanced in sensitive domains. The UNTP Decentralized Access Control specification likewise defines a privacy preserving architecture that allows more sensitive data to be accessible to authorized parties. Developing practical guidance on secure data-sharing techniques, such as encryption, anonymization and federated analysis, could help standardize safe practices for businesses contributing environmental insights without exposing proprietary details.

Supporting innovative data-sharing frameworks: New data sharing models are creating incentives for businesses to share data in exchange. For example, "data trusts" are subscription-based fiduciary entities where businesses contribute data in exchange for access to standardized, high-quality datasets shared by other participants. "This is Place" uses this model, applying common standards to ensure interoperability (Place, 2025). Meanwhile, "data spaces" are decentralized, interoperable digital ecosystems that enable controlled data sharing while preserving sovereignty and privacy.

Another increasingly influential approach is that of data spaces: decentralized, interoperable ecosystems that enable controlled, sovereign data sharing across sectors. These systems typically combine common technical standards, privacy-preserving architectures and multistakeholder governance models. A concrete example is the European Mobility Data Space (EMDS), which facilitates secure, cross-sectoral data exchange in the transport sector while ensuring that data providers retain control over access and usage. EMDS is part of the broader initiative to develop Common European Data Spaces, including the Green Deal Data Space (GDDS), which focuses specifically on environmental data. These EU-backed initiatives provide models for implementing federated data infrastructures that promote innovation, interoperability and data sovereignty. These models offer a means to balance openness and control, enabling environmentally significant data to be shared while protecting commercial and privacy interests.

Establishing selective redaction standards for sensitive supply chain data: Verifiable guarantee-of-origin information must remain accessible through multiple trades and lifecycle stages so that commercial incentives for more sustainable materials can function effectively. To balance traceability and confidentiality, standard protocols for digital selective redaction can help maintain transparency and traceability while protecting commercially sensitive information.

Establishing licensing frameworks to manage data usage: Publicly funded environmental data should be accessible for public good but clear frameworks must be in place to manage licensing, reuse and monetization. Standardized licensing models are needed to clarify data usage rights and prevent commercial actors from restricting access to publicly funded datasets while allowing fair use for innovation. For example, licensing frameworks can help ensure that revenues from commercialized public datasets contribute to data accessibility, for example by requiring private firms that profit from open government data to reinvest in maintaining open-access platforms.

Reducing dependency on single cloud providers: As environmental data infrastructure increasingly depends on commercial cloud providers, ensuring equitable and sustained access is essential. Promoting competition among cloud providers is important to prevent monopolization and ensure fair pricing. Creating some redundancy in cloud storage by distributing critical environmental datasets across multiple cloud platforms can also reduce risks of vendor lock-in, enhance data resilience and help ensure long-term availability.

Creating user-oriented data platforms

Challenges

Many environmental data platforms fail to meet the needs of non-expert users, decision-makers and marginalized communities, limiting their potential to influence advocacy, policy and action.

Lack of user-friendly and accessible platforms: Environmental data (e.g. satellite imagery, climate models) are often complex and therefore difficult to use for non-experts. Without effective data visualization and intuitive interfaces, non-technical stakeholders, including local governments, communities and advocacy groups, are excluded from using environmental data to support decision-making and environmental action. Data providers often focus substantial resources on making data available but neglect the final step of ensuring that data is organized and analyzed in ways that can support decision-making, for example in annual reports or dashboards.

Absence of feedback mechanisms: The absence of mechanisms for user feedback also perpetuates the disconnect between technical experts and general audiences. Most environmental data platforms lack feedback mechanisms, making it difficult to refine data quality, improve usability or adapt platforms based on evolving needs. Without channels for users to flag outdated or incorrect information, data platforms risk becoming static and less reliable over time.

Proliferation of platforms: Many institutions respond to usability gaps by developing entirely new platforms rather than improving interoperability between existing platforms. While the technical constraints of underlying architecture can mean that wholly new platforms are required to respond to evolving user needs, this process can lead to duplication of effort, wasted resources and a fragmented data landscape. In this context, users must navigate multiple sources to find relevant information. The proliferation of isolated platforms can further prevent the integration of complementary datasets, making cross-sectoral analysis more difficult.

Lack of long-term maintenance: Many environmental data platforms lack sustained investment in maintenance and updates, leading to their rapid obsolescence. A common issue in international organizations, including UN entities, is the creation of innovative, well-designed platforms that lose funding or institutional support within a few years. Without dedicated resources for ongoing platform upkeep, bug fixes and data updates, users often turn to newer initiatives, perpetuating a cycle where valuable platforms are abandoned. This squanders the resources invested in both the platform and related capacity-building.

Responses

To ensure that environmental data platforms effectively serve non-expert users, decision-makers and marginalized communities, there is a need for coordinated action to improve usability, feedback mechanisms, interoperability and long-term sustainability.

Prioritizing user-centered design: Environmental data platforms should be designed to meet the need of end-users, ensuring accessibility for policymakers, non-experts and marginalized communities. This includes building policy and action-oriented tools that link environmental issues to response measures, providing decision-ready insights rather than just raw data. A practical approach is to focus on high-impact use cases, starting with specific policy-relevant questions and working backward to determine the necessary datasets. The California Open Data Portal effectively applies this backcasting method, ensuring data collection efforts align with real-world decision-making needs.

Intuitive visualization and analysis tools should also be prioritized, allowing users to explore data without requiring advanced technical expertise. For example, the FAO EarthMap service provides a graphical interface that enables anyone to access key environmental datasets, integrating UNEP’s Strata methodology to combine environmental, climatic, social and security factors into a user-friendly decision-support tool. UNEP’s World Environment Situation Room (WESR) should embed similar design principles, ensuring accessibility for diverse user groups and linking environmental information to actionable policy insights. Its continued development should draw on lessons from leading platforms such as EarthMap, NASA's Earth Observing System Data and Information System (EOSDIS) and the Copernicus Climate Data Store.

Box 7.4 CITES Trade Database

The CITES Trade Database, managed for the CITES Secretariat by UNEP-WCMC, provides a centralized, publicly accessible repository of international wildlife trade data submitted by 183 Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). By requiring national authorities to submit trade data in a standardized format, CITES ensures that information is consistent, machine-readable, and useful for policy and research. The database enables governments, researchers and conservationists to track trade trends, identify potential illegal activity and inform biodiversity conservation efforts.

Using AI to enhance accessibility and inclusivity: Language models and AI-driven assistants can translate technical queries into plain language, help users explore complex datasets, and support real-time metadata generation. These tools are especially useful for non-expert users and institutions in low-capacity environments, helping to bridge semantic and linguistic gaps in data interpretation. One example is GeoGPT, a spatially aware language model designed to interpret and generate geospatial metadata, assist users in querying environmental datasets and provide explanations of trends in air quality, biodiversity or land use, without requiring deep GIS expertise. By bridging semantic and linguistic gaps, tools like GeoGPT expand access to spatial data infrastructure, particularly for non-expert users and institutions in low-capacity environments.

Engaging with users to improve platforms: To make environmental data platforms dynamic and responsive to user needs, data providers can introduce real-time feedback systems that allow users to report errors, outdated information, or usability issues directly within data platforms. Engaging user communities through regular consultations, surveys and participatory design processes can ensure that platforms evolve based on practical needs. For example, the Humanitarian Data Exchange platform by OCHA allows users to request missing datasets, flag issues and contribute feedback to enhance data quality and relevance. Establishing forums and knowledge-sharing spaces can further enable users to exchange best practices, raise challenges and suggest improvements.

Box 7.5 Copernicus Climate Data Store

The Copernicus Climate Data Store (EU, 2025) aims to provide a one-stop shop, offering access to climate data for research, policymaking information or commercial purposes. It is constructed around a process of continuous user-engagement, which aims to identify user needs and gaps in current capabilities. A User Requirements Database stores thousands of user requirements, which are regularly clustered and analysed and transformed into actionable recommendations to guide the development of the service. The Data Store also include a virtual assistant to guide users and user interactions are monitored continually to improve the responses. Users are also invited to provide direct feedback about their interaction with the virtual assistant by rating the response they receive.

Reducing platform duplication: Governments and organizations should move towards developing federated data ecosystems that connect and harmonize multiple sources, reducing duplication and increasing cross-sectoral collaboration. Designing modular, interoperable systems that allow different organizations to connect complementary tools and services rather than building isolated platforms.

Ensuring long-term maintenance and sustainability: investing in maintenance is essential for environmental data platforms to remain functional, relevant and widely accessible. To meet these resource needs, governments and funding agencies can establish dedicated long-term funding mechanisms for platform maintenance, covering essential aspects such as staffing, continuous data updates, bug fixes and user support. New environmental data platforms should include sustainability plans addressing updates and adaption to evolving data needs. Public-private partnerships can offer technical expertise and cloud infrastructure while maintaining public accessibility and interoperability. Using open-source tools and community-driven maintenance models can reduce reliance on short-term donor funding and enhance resilience.

Box 7.6 Digital for Climate (D4C)

Digital for Climate is a collaboration between international financial institutions, UN agencies and regulatory bodies aimed at building a modular, interoperable digital ecosystem for the carbon market. By coordinating workflows and integrating diverse data sources, D4C reduces platform duplication and enhances cross-sectoral collaboration. Its goal is to support a transparent, high-integrity global carbon market through efficient data exchange.

7.3 Summary of key responses

Table 7.1 summarizes the key actions proposed under each of the five thematic areas addressed under Pillar IV, spanning both national and international levels.

Table 7.1 Summary of key actions to enhance data governance

Focus area	Key actions
Ensuring that repositories are findable and accessible	• Strengthen data discovery and cataloging systems through open repositories (e.g. ODIS, OpenAIRE) and harmonized metadata standards (e.g. DCAT, STAC). • Improve accessibility of repositories by digitizing legacy data and ensuring non-proprietary, machine-readable formats (e.g. CSV, NetCDF). • Promote open, machine-readable ESG reporting formats and public data portals using open APIs and structured formats (e.g. XML, JSON, RDF). • Develop regional data repositories with long-term funding and coordination, ensuring that publicly funded data are stored in accessible formats. • Develop long-term preservation strategies for environmental data using federated storage models, integrity checks (e.g. blockchain) and sustainable funding.
Reducing cost barriers to data access	• Expand open access to publicly funded data by mandating open release policies and implementing global open data standards (see e.g. the UNESCO Open Science Recommendation).

	• Create incentives for data sharing through financial and technical support for countries adopting open data frameworks. • Develop open data platforms based on open standards and federated architectures (e.g. GBIF, Copernicus, World Bank Open Data). • Increase investment in national and regional infrastructure to reduce private cloud dependency and support affordable data storage and processing. • Create sustainable business models (e.g. tiered access, public-private partnerships, revenue sharing) to finance open data provision.
Balancing access against concerns about strategic and sensitive data	• Facilitate uptake of open data licences (e.g. Creative Commons) with decision-support tools to guide licensing choices. • Reduce bureaucratic barriers through digitized approvals, API-based authentication and compliance with transparency rules (e.g. Aarhus Convention). • Create classification frameworks and tiered access models to differentiate between open and restricted data and manage them responsibly. • Negotiate protocols to international agreements to align rules for sensitive data access (e.g. building on Nagoya Protocol or Aarhus frameworks). • Apply technical safeguards such as federated data sharing, distributed ledgers and privacy-preserving AI to enable secure use of sensitive data. • Reference frameworks such as the EU Data Governance Act, which offer mechanisms for data intermediation and data altruism, and promote responsible data sharing across public and private actors.
Navigating commercial interests and cloud dependency	• Incentivize broader access to private-sector environmental data through legal disclosure requirements, voluntary schemes and clearer materiality definitions. • Embed safeguards for secure private-sector data sharing through privacy-preserving architectures, encryption and trust frameworks (e.g. Gaia-X). • Support innovative sharing frameworks like data trusts and data spaces that align commercial and public interests. • Establish selective redaction standards to protect sensitive supply chain data while enabling traceability and downstream transparency. • Develop licensing frameworks that clarify reuse and monetization rights while ensuring open access to publicly funded datasets. • Reduce dependency on single cloud providers by encouraging competition, ensuring redundancy and safeguarding equitable access.
Creating user-oriented data platforms	• Prioritize user-centered design by aligning platforms with real-world decision needs and building intuitive, action-focused tools (e.g. FAO EarthMap). • Use AI to enhance accessibility through tools like GeoGPT that support plain-language queries, metadata generation and decision support.

	- Engage with users via real-time feedback, participatory design and community forums to ensure continuing platform relevance. - Reduce platform duplication by promoting federated data ecosystems and modular, interoperable systems that connect complementary tools. - Ensure long-term maintenance through sustained funding, open-source development models and partnerships that preserve accessibility and adaptability.

7.4 Overview of best practices in Pillar IV

Example	Section
OpenAIRE and ODIS offer federated discovery platforms that link environmental and scientific metadata across repositories, improving global data accessibility and reuse.	4.2.1 Ensuring that repositories are findable and accessible
NASA Earthdata and OCHA's HDX compile open-access datasets with standardized formats and tools that ensure discoverability, usability and informed decision-making.	4.2.1 Ensuring that repositories are findable and accessible
The INFORM project enables uninterrupted data collection from 14 Pacific Island countries, avoiding duplicative portals.	4.2.1 Ensuring that repositories are findable and accessible
Germany's national Geoportal.de metadata platform consolidates over 40 decentralized sources, offering a practical model for federated cataloging systems.	4.2.1 Ensuring that repositories are findable and accessible
ESAP centralizes ESG data across the EU, offering searchable, machine-readable access to support transparency and interoperability.	4.2.1 Ensuring that repositories are findable and accessible
The US requires that all federally funded research, including datasets, be made publicly accessible without embargo	4.2.2 Reducing cost barriers to data access
World Bank initiatives offer technical assistance and funding to countries that commit to open data policies.	4.2.2 Reducing cost barriers to data access
The Copernicus Programme, the USGS Landsat Program, the World Bank Open Data Initiative, the Livable Planet Explorer and GBIF all provide free access to critical data.	4.2.2 Reducing cost barriers to data access
El Salvador delivers agroclimatic data to farmers using mobile apps and is exploring monetizing weather-related datasets to generate sustainable funding streams.	4.2.2 Reducing cost barriers to data access
The Development Data Partnership helps global organizations access private data for development and is expanding tools to scale alternative data use.	4.2.2 Reducing cost barriers to data access

Online Access to Research in the Environment (OARE) offers model for equitable access to environmental research publications in low- and middle-income countries.	4.2.2 Reducing cost barriers to data access
GBIF applies Creative Commons licenses to biodiversity data, enabling open reuse while allowing attribution and non-commercial restrictions where needed.	4.2.3 Balancing access against concerns about strategic and sensitive data
The Aarhus Convention defines rules and criteria that ensure transparency and help determine when access restrictions are justified.	4.2.3 Balancing access against concerns about strategic and sensitive data
The Nagoya Protocol regulates the sharing of genetic resources and associated data while ensuring that participating countries maintain sovereignty	4.2.3 Balancing access against concerns about strategic and sensitive data
The EU Satellite Centre enables sensitive geospatial data to be used securely in government and security applications, while maintaining strict governance over access.	4.2.3 Balancing access against concerns about strategic and sensitive data
Trust federations such as EOSC and GAIA-X establish secure networks where participants can share sensitive data under mutual trust agreements within a federated data ecosystem.	4.2.3 Balancing access against concerns about strategic and sensitive data
EU data spaces like EMDS and GDDS show how federated, interoperable systems enable secure data sharing while balancing openness, sovereignty, and privacy.	4.2.4 Navigating commercial interests and cloud dependency
CITES requires standardized trade data submission for its Trade Database, ensuring consistent, machine-readable data for policy, research and the CITES Review of Significant Trade.	4.2.5 Creating user-oriented data platforms
The California Open Data Portal uses a backcasting method to align data collection with decision-making needs.	4.2.5 Creating user-oriented data platforms
EarthMap provides a graphical interface, combining environmental, climatic, social and security factors into a user-friendly decision-support tool	4.2.5 Creating user-oriented data platforms
The Copernicus Climate Data Store is built with continuous user-engagement, to identify gaps and user needs.	4.2.5 Creating user-oriented data platforms
D4C reduces platform duplication and enhances collaboration across international organizations, helping create a transparent global carbon market.	4.2.5 Creating user-oriented data platforms

8 Pillar V: Capacity-building

8.1 Scope and vision

The capacity building pillar includes measures to develop the broad range of capacities needed for effective environmental data governance: data collection, processing, sharing, communication and use in policymaking processes. This includes:

- training, guidance and tools to build skills and knowledge in essential areas;
- investments in physical infrastructure and hardware ranging from monitoring equipment and data repositories to data processing and communication infrastructure;
- sustainable funding for investing in areas such as operational costs, data access and research;
- fostering the exchange of best practices and innovative solutions to enhance data collection, processing and dissemination.

In the capacity-building context, achieving GEDS vision would imply that, in 2035, all stakeholders within the global environmental data ecosystem are empowered with the skills, knowledge, infrastructures and tools needed to gather, analyse and use environmental data effectively. It ensures affordable and reliable storage solutions and secures sustainable financial support for long-term impact. This system bridges the gap between data, policymaking and decisions, transforming environmental data into a powerful tool for global collaboration and sustainable development.

8.2 Key challenges and potential responses

Developing foundational ICT infrastructure

Challenges

Strong ICT infrastructure is essential for accurate, secure and continuous environmental data collection, processing, reporting and dissemination. At present, many countries face significant challenges in terms of environmental monitoring hardware, connectivity and data transmission, storage and processing power. These issues are especially pronounced in low- and middle-income countries, where limited investment in digital infrastructure restricts the availability and quality of environmental data.

Deficient environmental monitoring hardware and equipment: Many countries lack in-situ monitoring stations such as weather stations, water quality sensors and air pollution monitors, which are essential to generate reliable environmental data. Even where monitoring networks exist, they are often outdated, difficult to maintain or suffer from limited calibration, reducing data accuracy. Many low-income countries struggle to deploy IoT sensor networks or low-cost community-based monitoring devices, restricting their ability to collect real-time data. Uneven access to high-resolution remote sensing and satellite data further creates blind spots in global environmental monitoring.

Poor connectivity and data transmission: Many remote areas, where environmental monitoring is often critical, lack the necessary broadband, mobile or satellite network infrastructure to transmit data reliably. Even in urban areas, slow internet speeds, high data transmission costs and a lack of secure networks hinder environmental agencies, research institutions and the public from retrieving, analyzing sharing environmental datasets. The lack of affordable cloud computing services and high-performance computing solutions further exacerbates disparities, making it difficult for under-resourced institutions to store and process large datasets such as satellite imagery and climate models. Without robust digital infrastructure, environmental data remains fragmented and inaccessible, reducing its potential impact on policy and decision-making.

Insufficient capacity for data storage and processing: Many environmental agencies still rely on outdated digital systems that are incompatible with modern data platforms, making integration and retrieval cumbersome. Additionally, the lack of national or regional data repositories forces many institutions to rely on expensive commercial cloud services, which are often unaffordable or restricted due to sovereignty concerns. The growing complexity of environmental datasets, particularly high-resolution geospatial, IoT real-time sensor data, demands significant computing power, which many organizations lack. In some cases, institutions are unable to process the data they collect due to insufficient server capacity, outdated hardware, or the absence of scalable storage solutions such as data lakes or federated cloud architectures. Emerging solutions like blockchain for tracking data provenance and edge computing for real-time processing remain largely inaccessible to many lower-income countries, further deepening the digital divide in environmental data governance.

Responses

Enhancing environmental monitoring capabilities: Governments, international organizations and research institutions should take the lead in enhancing national-level monitoring hardware and equipment. National governments can provide funding and regulatory support to expand investment in modern, cost-effective sensors, such as IoT-enabled weather stations, water quality sensors and air pollution monitors, ensuring real-time, high-resolution data collection. International organizations, including United Nations entities and the World Bank could facilitate technology transfer and partnerships between developed regions and low- to middle-income countries, enabling access to advanced monitoring tools and satellite data. Civil society groups and academic institutions can promote community-based monitoring initiatives, supporting citizen science projects and local efforts to deploy simple, affordable monitoring solutions in areas lacking formal infrastructure.

Investing in connectivity: Improving connectivity and data transmission action from both governments and the private sector, particularly telecommunications companies. Governments should prioritize investments in broadband, mobile and satellite networks, particularly in remote regions, ensuring equitable access to environmental data infrastructure. Businesses have an important role in developing localized cloud and edge computing solutions that allow data to be processed closer to source, reducing dependence on centralized high-speed networks.

Strengthening data storage and processing capacity: Public investments in scalable, interoperable data platforms are important for storing and handling large and complex environmental datasets. National data hubs can serve as centralized platforms for aggregating data from multiple agencies, improving accessibility, and supporting integrated analysis. Regional data repositories can also play an important role, as SPREP has shown in the Pacific region. International organizations and regional development banks can help establish such resources, ensuring secure, standardized and long-term data accessibility while reducing reliance on expensive commercial cloud services. Technology firms, research institutions and open-data advocates can explore innovative storage solutions, including data lakes and federated cloud architectures to improve the management of high-resolution geospatial and sensor data.

An example of this approach is the EU's Destination Earth (DestinE) initiative. It is developing a federated digital twin of the planet using Europe's high-performance computing and shared data infrastructure. DestinE integrates environmental, climate, and socio-economic data from multiple sources using common standards, offering a practical model for large-scale, interoperable data systems that support policy and decision-making.

Mapping infrastructure gaps to guide action: In partnership with regional and domain-specific organizations, UNEP could support efforts to map disparities in connectivity, sensor coverage and data storage capacity. Such assessments would serve as a foundation for identifying investment priorities, shaping capacity-building strategies and designing targeted infrastructure programmes. To translate these insights into concrete improvements, UNEP could convene multistakeholder dialogues, bringing together governments, regional development banks, private sector actors, and research institutions, to co-develop coordinated solutions and financing strategies aimed at closing environmental data infrastructure gaps in underserved regions.

Ensuring access to data management and processing resources

Challenges

Limited access to modern data storage solutions: Many institutions lack access to scalable and flexible data storage solutions, forcing them to rely on fragmented, isolated databases that are difficult to integrate or analyze at scale. Traditional databases are not optimized for high-resolution satellite imagery, large geospatial datasets, or continuous real-time sensor data, leading to slow retrieval times, inconsistencies data silos. Data lakes and distributed cloud storage provide scalable alternatives for storing and structuring unstructured or high-frequency environmental data, yet adoption has been slow. Many governments and research institutions lack the necessary funding, infrastructure expertise to transition to modern data storage solutions. Additionally, concerns over data sovereignty, privacy cybersecurity risks have slowed the adoption of distributed cloud systems, leaving many countries dependent on external service providers.

Gaps in cloud-based environmental data processing: The increasing volume of environmental data from satellite imagery, IoT sensors and geospatial models requires high-performance computing and cloud-based processing platforms to be analyzed efficiently. Cloud computing platforms such as Google Earth Engine, Open Data Cube and AWS Earth offer real-time environmental analytics, large-scale climate modeling and geospatial data processing, but these tools remain out of reach for many institutions due to cost constraints, lack of cloud policies and data sovereignty concerns. In many cases, environmental data is processed manually or using outdated systems, slowing down climate response efforts and making predictive modeling difficult.

Limited access to advanced analytical tools: Many analytical tools, including cutting-edge computer vision, machine learning and geospatial analysis tools are proprietary, expensive or difficult to access for researchers, local governments and communities in developing regions. This unequal access to analytical capabilities reinforces global data inequalities, making it harder for resource-constrained actors to conduct high-quality environmental assessments or contribute meaningfully to global environmental data initiatives. While open-source tools and platforms could offer cost-effective alternatives to proprietary solutions, uptake is often weak gaps in knowledge and skills.

Wasted resources in developing tools: Environmental data analysis is further hampered by duplication of efforts and inefficiencies in tool development. Lack of coordination among governments, research institutions and private-sector actors leads to fragmented and redundant efforts, where multiple entities develop similar tools independently rather than collaborating to create shared, open-source solutions. This lack of alignment wastes resources, limits interoperability and prevents the broader adoption of cost-effective analytical tools.

Limited access to AI-powered data validation and enhanced analysis: As noted in Pillar III, AI and machine learning models can be used to detect anomalies, reconstruct missing values validate data accuracy. At present, however, adoption remains low due to technical complexity, lack of expertise and cost barriers. For example, satellite-based environmental monitoring could be enhanced with AI-powered image recognition, yet many institutions lack the computing power and trained personnel to deploy these solutions at scale. This problem is further compounded poor integration of remote sensing data (e.g. Sentinel, MODIS, Landsat) into national monitoring systems.

Weak uptake of blockchain, federated AI and other emerging reporting and security tools: Blockchain-based reporting, federated AI learning models and decentralized data management systems could improve environmental data security, transparency accessibility, but these technologies remain underutilized. Blockchain can help prevent data tampering and improve trust in environmental impact reports, yet it is rarely integrated into national environmental reporting systems. Similarly, federated AI models allow multiple institutions to analyze environmental data while preserving privacy, but technical complexity and lack of expertise limit their deployment. Many government agencies lack clear policies or guidance on how to incorporate these tools, or needed skills and knowledge to implement them.

Responses

Expanding access to modern data storage solutions: Governments, in collaboration with international organizations, should prioritize funding and policy incentives to help institutions transition to scalable, cloud-based or decentralized data storage solutions. Businesses, particularly cloud service providers, could contribute by offering "data commons" models, i.e. low-cost cloud storage tiers for environmental data to support research and public-interest projects. At the same time, the development of localized distributed cloud infrastructure, including edge storage and hybrid cloud solutions, could help countries reduce dependence on external providers while addressing data sovereignty concerns. Governments should also incentivize the adoption of open-source data management frameworks, ensuring that institutions have access to low-cost, interoperable storage solutions.

Bridging gaps in cloud-based environmental data processing: Governments can facilitate cloud adoption for environmental data by updating regulatory frameworks and developing standardized data-sharing agreements that address concerns around sovereignty and privacy. As with cloud storage, governments could also negotiate licensing agreements with software developers to allow free or discounted access to essential analytical tools for non-commercial environmental applications, ensuring that even resource-limited institutions can leverage advanced computing power. For their part, tech companies could expand environmental computing grants that provide subsidized or free access to high-performance cloud platforms for researchers and government agencies working on climate and environmental challenges.

Enhancing coordination and reducing inefficiencies in tool development: Governments and multilateral organizations could establish global and regional working groups to improve coordination, ensuring that tool development efforts align with shared technical standards and interoperability requirements. Funding mechanisms could encourage the development of modular, open-source and adaptable tools rather than siloed, proprietary solutions. Developing platforms and tools optimized for low-bandwidth regions can help ensure access for underserved communities. Best practices can be drawn from collaborative initiatives such as the European Open Science Cloud (EOSC) and OpenAIRE, which facilitate the sharing and reuse of analytical tools across multiple institutions. By fostering joint development efforts and prioritizing interoperability, stakeholders can maximize the impact of available resources while creating more sustainable, widely applicable analytical tools. UNEP and its partners could support these efforts by developing and disseminating best-practice guidance on cost-effective sensors, IoT-enabled monitoring devices and community-based approaches, helping countries identify appropriate technologies for their specific needs.

Improving access to advanced analytical tools: To ensure sustained access to advanced analytical tools, governments and international organizations could promote and fund open-source initiatives, such as Open Data Cube and QGIS and invest in their continued development and maintenance. Governments and international organizations could establish innovation hubs, facilitating collaboration between software developers, scientists and policymakers to build and maintain open analytical tools, such as open computer vision and AI models designed for environmental monitoring, ensuring that their designs, code datasets are freely available to the public.

Governments and research institutions could open analytical tool repositories: global or regional hubs where researchers and policymakers can access free or low-cost analytics software for environmental modeling. They could also further promote uptake of open-source tools by developing training programmes and guidance tools. Equally important is ensuring transparency in the methods, assumptions and models used, so that users can trust, interpret and replicate analytical results. Open methodologies, documented workflows and auditable data pipelines should be prioritized to build trust and enable informed participation.

Box 8.1 Democratizing environmental data processing: SEPAL and DEA

Integrating low-cost, cloud-based analytical platforms into national and regional environmental data systems could further help democratize access to computationally intensive tools. For example, FAO's System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) provides countries, particularly in the developing regions, with cloud-based geospatial analysis tools to support forest monitoring and climate reporting (e.g., REDD+ programmes). Similarly Digital Earth Africa employs the Open Data Cube platform to enable African nations to analyze Earth observation data for applications like agriculture, water monitoring and urban planning.

Building needed skills and knowledge

Challenges

As indicated already in Chapters 2-5, gaps in knowledge and skills are pervasive problems across all areas of this strategy, undermining data governance, data quality, interoperability and accessibility. Many countries, particularly in developing regions, lack the baseline competencies to participate in the global environmental data ecosystem. In some countries and sub-national regions, there is limited understanding of what data to collect, how to calibrate and maintain monitoring systems, how to validate and track provenance, how to undertake statistical analysis and how to transform data into actionable products that can inform policy and action.

To the extent that domain-specific tools, methodologies and guidance are available, they are often underutilized due to limited awareness. Governments and institutions often reinvent processes rather than building on existing best practices or contributing to the development of shared, open-source solutions. This lack of coordination wastes resources, limits interoperability and prevents the broader adoption of cost-effective analytical tools.

In many countries, gaps in essential skills and knowledge exist across the full data lifecycle:

- **Data needs assessment and system design**: Developing effective environmental data systems requires clear objectives, aligned with legal mandates, sustainability goals and ethical considerations such as data sovereignty. In practice, efforts suffer from a lack of expertise in identifying key data needs, resulting in inefficient or redundant data collection. Weak monitoring framework design leads to poor policy integration, while limited stakeholder engagement results in data that does not address real-world needs. Interdisciplinary collaboration is often weak, preventing effective coordination between scientists, data experts and policymakers. For example, limited understanding of the supply-demand dynamics of Earth observation services for climate adaptation can lead to misalignment between data providers and end-users, particularly in vulnerable regions.
- **Data collection and acquisition**: Effective environmental data collection requires technical expertise in deploying, calibrating maintaining monitoring systems, yet many organizations lack the necessary skills. Inconsistent methodologies create gaps in accuracy and comparability, while inadequate training, particularly in remote and resource-limited regions, results in poor data coverage. Poorly structured data collection surveys compromise the completeness and reliability of environmental datasets. Shortages of trained personnel in remote sensing and in-situ monitoring contribute to data gaps and biases. The lack of mobile app development expertise for field data collection reduces efficiency and real-time usability, further exacerbating data quality issues. A lack of relevant expertise hinders the uptake of emerging technologies such as IoT sensors, drones and autonomous systems.
- **Data processing and management**: Once collected, data must be cleaned, structured managed efficiently but insufficient training in data management practices and QA protocols leads to errors

and inconsistencies. Many professionals lack skills in data cleaning, handling missing values, identifying outliers and addressing biases. Automation through AI and machine learning could improve data validation but expertise in these techniques is often scarce. Lack of knowledge about data formats and standards causes integration challenges, limiting interoperability and discoverability. Technical gaps in frameworks like Geospatial Data Abstraction Library (GDAL), semantic data structuring and API development hinder effective data processing and accessibility. Inadequate capacity in drafting terms of reference affects system development in areas such as big data management, geospatial processing and API integration.

- **Data storage and security**: Many organizations lack the technical expertise to maintain reliable data systems. Weak database engineering skills result in inefficient and insecure storage structures, while limited experience with cloud platforms (AWS, Azure, Google Cloud) leads to inefficiencies in storage, retrieval and cost optimization. Poor data archiving and backup practices create risks of loss or redundancy, particularly for large-scale datasets such as satellite imagery. Inconsistent metadata documentation makes it difficult to track data provenance, impacting long-term usability. Additionally, gaps in cybersecurity capabilities expose environmental datasets to data breaches and unauthorized access, jeopardizing sensitive information.
- **Data sharing and interoperability**: Limited understanding of data standards and frameworks hinders interoperability, accessibility and cross-platform integration. Weak API development skills prevent data exchange poor metadata management reduces discoverability and usability. Data licensing and governance issues further complicate collaboration, as unclear policies limit data sharing between institutions. Additionally, gaps in semantic data descriptions, GDAL expertise and open-data frameworks restrict efforts to harmonize datasets across different regions and disciplines.
- **Data analysis and interpretation**: Many organizations lack essential skills in data analysis, making it difficult to extract meaningful insights from complex datasets. Weak statistical capacity and GIS expertise limit the ability to analyse multi-variable environmental data, while insufficient knowledge of uncertainty analysis and error propagation undermines confidence in data-driven conclusions. There is also a global disparity in AI and machine learning adoption. Many countries struggle to meaningfully integrate advanced technologies due to resource constraints, resistance to change and skill gaps. Limited expertise in environmental modeling and simulation weakens scenario-based assessments for climate, hydrology ecosystems, while poor remote sensing capabilities hinder the full utilization of satellite data. Moreover, new digital tools for circular economy tracking (e.g., lifecycle analysis, digital product information systems) remain underutilized.
- **Data communication and visualization**: Weak communication capabilities mean that data are seldom transformed into clear, actionable insights capable of engagement and mobilizing different audiences and reducing the impact of scientific findings. Expertise is often lacking in user-centered design. data storytelling and visualization tools (e.g., Tableau, Power BI, Matplotlib), reducing the accessibility of data tools and platforms. Weak uncertainty communication leads to misinterpretations of environmental risks and trends. Data analysts and communication specialists rarely collaborate, further limiting the clarity and influence of data-driven narratives.

- **Integrating data into assessment and policy**: Limited training in data-driven decision-making, means that policymakers often lack data analysis skills, preventing them from leveraging data for evidence-based governance. Additionally, stakeholders across disciplines struggle to collaborate, as social and professional divides create barriers to effective dialogue. The absence of structured feedback loops between data producers and policymakers reduces the relevance of available datasets, leading to a disconnect between science and policy implementation.
- **Corporate data capacity gaps across public and private sectors:** Many governments, particularly in developing regions, lack the institutional capabilities to assess, verify and regulate corporate environmental disclosures and product-level data, weakening oversight and transparency. This is also the case for LCA data generation and storage capacity, which requires significant technical expertise to review and provide necessary quality assurance of LCA databases. At the same time, small and medium-sized enterprises (SMEs) and supply chain actors often lack the tools, expertise and technical support needed to generate high-quality environmental data or comply with evolving reporting requirements. These gaps limit the credibility and completeness of corporate data and undermine efforts to build integrated, trustworthy environmental information systems.

Flawed approaches to capacity development: There is clearly a huge need for investments in capacity development. Yet past interventions have sometimes been designed in ways that do not achieve their goals. For example, where capacity-building is donor-driven, it can tend to focus on short-term training, rather than fostering long-term expertise and institutional resilience. Capacity-building efforts often also target central government institutions, while local governments and community-level organizations, which play a critical role in environmental monitoring, are left out. In some instances, donor countries take raw data from low-income countries and use it to develop tools for them. Even when these tools are useful, such practice maintain the imbalance of skills and knowledge between developed and developing regions. Opportunities to develop local expertise are sometimes squandered, for example when projects in developing countries rely on international consultants. The result is to perpetuate dependency rather than building self-sufficiency.

Slow and rigid learning processes: Traditional bureaucratic structures, rigid policy frameworks, and static training models result in slow adoption of emerging technologies such as AI-driven analytics, cloud-based data integration, and decentralized data infrastructures. Many capacity-building initiatives focus on one-time training programs rather than fostering continuous learning ecosystems that adapt as technologies and best practices evolve rapidly. Without more agile and iterative approaches, environmental data governance risks becoming outdated, reducing its ability to support timely, evidence-based policymaking and climate action.

Responses

Building knowledge and skills is essential to improve data governance, quality, interoperability and accessibility. It is also imperative to address the digital divide both between and within countries. But capacity-building efforts need to plan for the long term, for example by establishing programmes in universities and preparing for what happens when people move to new posts or countries. The objective is not just to create new capabilities but rather systems that advance capabilities.

Capacity-building efforts should prioritize inclusivity and accessibility, ensuring that developing countries, Indigenous communities and marginalized groups have equal opportunities to engage in environmental data governance. For example, online courses, certification programs and regional training hubs can all help ensure equitable access to technical education, particularly in developing countries and small island states.

Training programmes should be available in multiple languages, adapted to local contexts delivered through both online and in-person formats. Special attention should be given to gender equity in environmental data leadership, ensuring that women and underrepresented groups are empowered to participate in decision-making.

Creating open-access digital learning platforms: International organizations, tech companies and academic institutions could collaborate to develop free, multilingual online learning platforms. These could offer courses, guidance and other resources, addressing the broad range of capacity building needs across the data pipeline, with an emphasis on open-source tools. Initiatives such as "AI for Earth" and NASA's Applied Remote Sensing Training (ARSET) are strong examples of platforms that democratize knowledge and provide structured training.

Embrace agile, continuous learning approaches: Governments should implement modular, adaptive training programs that evolve alongside technological advances. Creating cross-sectoral collaborations with tech companies, research institutions and international organizations can facilitate continual knowledge transfer and upskilling of data practitioners and policymakers.

Establish regional knowledge hubs: Capacity transfer and knowledge sharing within regions is often particularly valuable. Regional knowledge hubs, connecting governments, universities and international organizations can provide training and technical assistance, and develop relevant e-learning platforms, as SPREP has done in the Pacific region (SPREP, 2021b, 2024). They can also provide feedback to the global system, highlighting regional and national needs and support peer-to-peer knowledge exchange programmes. This would promote localized, context-specific solutions tailored to different regions' technical and regulatory environments. In parallel, exchange programmes for technical staff and researchers could foster knowledge-sharing between institutions in different regions. This is especially important for technical domains such as ocean accounts, where developing institutional capacities not only enables effective data generation and use but also positions lead agencies to share knowledge with other relevant national institutions.

Box 8.2 Enabling structured capacity-building through IPBES processes

The IPBES assessments provide a strong model for structured capacity-building through their data management reports, which guide users in recreating analytical processes and collecting data in a standardized manner. These reports are complemented by expert-led training programs designed to help stakeholders understand and apply relevant tools. By prioritizing open standards and avoiding formats that require costly proprietary licenses, IPBES ensures that access to environmental data and methodologies remains equitable.

Develop public-private partnerships for cloud and AI skills development: Governments could partner with tech companies such as Google, Microsoft and Amazon to establish training grants, fellowships mentoring programmes that build expertise in AI-powered environmental analytics, geospatial modeling high-performance cloud computing. These programmes could prioritize researchers and government agencies in low- and middle-income countries, ensuring equitable access to technical skills.

Build local advanced tech talent pipelines: Governments and universities should integrate advanced tech into higher education curricula, ensuring that the next generation of environmental professionals is trained in advanced data technologies such as machine learning techniques for environmental monitoring; big data management and cloud computing solutions; federated AI models for decentralized analysis; and blockchain for data integrity and trust in environmental reporting. Scholarship programmes could support students from underrepresented regions in studying environmental data science.

Bridge the supply and demand sides of environmental data services: Workshops could connect environmental data users (government agencies, NGOs researchers) with service providers (tech firms, satellite data companies and AI developers). These sessions would foster practical collaboration and ensure that technological innovations align with real-world needs. The World Bank's Digital Earth Partnership, with its focus on EO services and a Space Data Facility, could provide a useful model for such initiatives.

Develop programmes on AI literacy and ethics: There is a need for AI literacy programmes tailored for policymakers and regulators, equipping them with a foundational understanding of AI's capabilities, limitations and the implications for environmental governance. Online programmes or guidance documents could address AI-driven environmental analytics, ethics and bias awareness training and best practices of AI-driven environmental initiatives.

Strengthening capacity for corporate environmental disclosures: Governments and development partners should prioritize capacity-building programmes for public authorities to enhance their ability to assess and validate ESG and product-level disclosures. This includes training in environmental data auditing, digital reporting platforms and verification protocols to ensure that corporate claims are accurate, consistent and comparable. At the same time, targeted support is needed for private-sector actors to build the skills, systems and knowledge required to comply with evolving sustainability reporting requirements.

UNEP's Finance Initiative already supports this agenda. UNEP FI guidance documents, capacity-building workshops, pilot programs and peer-learning platforms help financial institutions (especially in emerging markets) strengthen their disclosure practices and align with global frameworks. UNEP FI supports voluntary action ahead of regulation, helping institutions prepare for the legally binding disclosure mandates that are currently emerging. For example, UNEP FI Regulatory Implementation Support Programme holds regular data discussions with relevant actors, regulators and financial institutions to discuss needs and options in the sustainability disclosures field. At the product level, UNEP's Life Cycle Initiative provides basic capacity development for the use of LCA in policymaking, and also for LCA data generation and the maintenance of national LCA databases, although the necessary scale up requires significant concerted efforts and resources.

Strengthening institutional capacities

Challenges

Problems securing and retaining needed skills: Environmental data governance faces a critical shortage of skilled personnel. The rapid growth of AI, cloud computing and blockchain-based transparency mechanisms has intensified competition for technical talent, making it difficult for government agencies to attract and retain skilled professionals. This staffing gap limits the adoption of emerging technologies and weakens the ability of governments to implement real-time environmental monitoring, big data analytics and integrated data governance systems. Additionally, high staff turnover results in knowledge loss and inconsistent data management. Many institutions struggle to retain trained personnel, leading to disruptions in data continuity, validation processes and system maintenance. The lack of structured career pathways, competitive salaries and professional development opportunities exacerbates these challenges, driving talent toward the private sector or international organizations.

Weak institutional mechanisms linking environmental data into policymaking: Even when environmental data are available, governments and intergovernmental bodies often lack the systems and processes to use the data fully in assessments and decision-making. For example, cities often lack governance frameworks to use real-time data in policies and actions such as disaster response (Evans et al., 2024). Often data are not transferred into appropriate products and knowledge that can support policymaking.

Limited formal structures for public–private coordination: In most countries, institutional engagement between regulators, national statistical offices and corporate environmental data providers remains weak. There are few structured mechanisms to align data planning, quality standards and reporting requirements across public and private actors. This results in fragmented data governance, missed opportunities for interoperability and duplicated reporting burdens. Without formal coordination platforms or shared protocols, governments struggle to incorporate corporate disclosures into national systems and businesses lack clarity on how their data contribute to policy, compliance, or public environmental goals. As the Biancotti et al. (2021) have emphasized, building principled, trust-based public–private data partnerships is essential for improving the quality, accessibility and utility of environmental data in decision-making.

Responses

Institutional innovations: Creating dedicated units within national administrations can help in overseeing environmental data collection across government, ensuring compliance with standards and coordinating the activities of departments and agencies. In France, for example, the *Secrétariat général pour la Transition Écologique* is located within the office of the prime minister, which puts it in a strong position to initiate and drive forwards efforts to improve environmental data governance. Creating dedicated interdepartmental teams or committees can likewise help streamline the integration of environmental data across government. By breaking down silos between ministries and agencies, governments can ensure that data flows seamlessly from different sources. They can also help foster a shared language among specialists from different disciplines, helping bridge conceptual divides between environmental scientists, data engineers, and policy analysts.

Creating structured career pathways and incentive programmes: Scholarships, internship programmes and fast-track hiring schemes for data specialists in government agencies can help recruit young professionals into public sector environmental data careers. For example, the European Space Agency offers early-career fellowships for Earth observation and remote sensing scientists, ensuring a pipeline of skilled professionals in public institutions. Creating structured career paths with competitive salaries, promotion tracks and professional development opportunities are also important to retain talent. In developing country contexts, partnerships with philanthropic foundations could help finance ongoing training and career development opportunities, helping retain talent in public institutions.

Building capacities and tools for improved data governance: Combining open government initiatives with a commitment to evidence-based policymaking creates strong incentives for data sharing and collaboration. Officials should be equipped not only with technical skills but also with an understanding of how to use data to inform impact assessments, disaster response and long-term strategic planning.

IT platforms can further facilitate coordination and the uptake of environmental data in integrated assessments and public policy. Developing platforms or dashboards that transform environmental data (including near real-time data) into accessible, visual information is also vital. Including a focus on policy tracking in these platforms can help link environmental data directly to decision-making processes.

Ensure public–private institutional coordination: To strengthen alignment between regulatory frameworks and corporate environmental data systems, governments can establish formal coordination mechanisms such as public–private working groups, advisory panels or technical committees. These structures can promote coherence in data standards, metadata schemas, and classification systems, while also helping to align national regulatory systems with emerging corporate disclosure frameworks (e.g. the EU's EFRAG Sustainability Reporting Board for corporate sustainability disclosures). Drawing on principles outlined by Biancotti et al. (2021), such mechanisms should be designed around transparency, trust, reciprocity, and shared value. Rather than viewing corporate data merely as an input to regulatory systems, public–private data partnerships should establish clear expectations, responsibilities, and safeguards on both sides. These include clarity on data access, attribution, privacy protections and the intended use of shared datasets. By embedding such principles, governments can improve interoperability, reduce reporting burdens and foster more cooperative data ecosystems that serve public and private interests alike.

Box 8.3 **Net Zero Data Public Utility**

The Net Zero Data Public Utility (NZDPU) is a collaborative data partnership supported by UN agencies, financial institutions and data providers. Its mission is "to provide a trusted, central source of company-level climate data that is transparent and openly accessible to all". Focused on greenhouse gas emissions, NZDPU is developing a federated, open-access platform for high-quality corporate climate disclosures. It exemplifies how shared data infrastructure can build trust, support interoperability, and strengthen coordination between public and private actors in environmental disclosure systems.

Securing sustainable funding for data governance

Challenges

Building national capacities for environmental data governance is expensive. Constructing basic ICT infrastructures, ensuring access to data storage and process, developing and retaining knowledge and skills, and building institutional capacities all require major investments and sustained, long-term financial expenditure. This represents a critical challenge, particularly in low-income countries where funding is often short-term, fragmented and heavily reliant on external donors.

Lack of dedicated national budgets for environmental data systems: In many countries, governments are reluctant to commit to long-term and sustained spending data collection, processing and storage. In developing regions, environmental monitoring initiatives often rely on short-term, project-based funding, leading to data discontinuities and gaps when funding cycles end. This prevents the establishment of long-term monitoring frameworks, making it difficult to track environmental trends over time and develop comprehensive datasets. Many local governments lack the resources to establish detailed environmental monitoring programmes or to upgrade old and worn out equipment.

Even in wealthier nations, funding for environmental data systems competes with other social and economic priorities, particularly during times of economic strain. As a result, key environmental data infrastructure, such as real-time monitoring networks, Pollutant Release and Transfer Registers and geospatial data processing systems, remains underfunded, outdated or entirely absent in many regions – although the EU's e-PRTR system and its successor, the Industrial Emissions Portal, are notable exceptions. The lack of stable financing also affects human resources, as many environmental agencies struggle to retain skilled personnel for data collection and management due to budgetary constraints. Without dedicated and recurring funding allocations, environmental data systems remain fragile, inconsistent unable to fully support evidence-based policymaking.

Lack of funding for data maintenance, storage and long-term access: Many environmental monitoring initiatives receive initial funding for data collection but lack the financial support needed for ongoing validation, updates and archiving, resulting in orphaned datasets that degrade in quality over time. Public agencies and universities often struggle to allocate resources for long-term data stewardship, as funders typically prioritize new research over maintaining existing datasets. In the NGO sector, funding constraints and donor requirements frequently mean that data are not properly stored, shared or made publicly available, as organizations lack the staff and financial capacity to maintain repositories. Without clear ownership structures and dedicated funding for long-term data management, critical environmental datasets risk becoming inaccessible, unreliable, or permanently lost.

Responses

Achieving effective environmental governance will depend on dedicated national budgets, clear investment strategies and private-sector engagement.

Securing national budgets for environmental data governance: Governments should integrate environmental data governance into national budgets and mainstream it within broader development plans. The Global Environment Facility (GEF) and the Green Climate Fund (GCF) provide funding for environmental data collection and capacity-building, and their contributions could be further leveraged to strengthen national data systems. Legislative mandates can also help secure continuous budget allocations, ensuring environmental monitoring does not become an afterthought. To generate revenues for environmental data collection and management, governments can introduce environmental data service subscriptions, where businesses and industries pay for access to high-quality environmental datasets. Financing mechanisms such as carbon markets, green bonds and environmental impact funds can be leveraged to generate dedicated funding for long-term environmental data management. Demonstrating the economic and social value of environmental data, particularly for sectors such as agriculture, disaster preparedness and public health is also important as a means to justify sustained investments in monitoring and data governance.

Mobilizing private sector, philanthropic and international partnerships: Given the competing financial demands on national budgets, partnerships with businesses, philanthropic organizations and international donors are essential to ensure sustainable financing for environmental data systems. Public-private partnerships offer a way for governments to share the financial burden of environmental data infrastructure with industry, while also ensuring that critical datasets remain operational and accessible over time. Initiatives like the EU/Finnfund Africa Connected Programme, which improve ICT infrastructure and reduce cost barriers, can significantly lower barriers to digital transformation in environmental data governance. Large philanthropic organizations can also play a key role in supporting environmental data initiatives, particularly in low-income countries where government funding is scarce. Development aid and funding from international financial institutions needs to be organized strategically to ensure environmental monitoring systems are not only established but maintained over time.

Ensuring sustainable funding for data maintenance, storage and long-term access: Governments and international organizations can establish dedicated funding streams for data stewardship, ensuring that environmental data remains accessible, reliable and usable beyond the duration of short-term projects. One solution is to create centralized, well-funded national and regional data repositories that provide secure, long-term storage for environmental datasets. Multi-year funding models are crucial for sustaining capacity-building programs in environmental data governance, ensuring continuous training, technological updates and institutional knowledge retention. Governments, NGOs the private sector must work together to integrate environmental data maintenance into broader financial frameworks, such as climate adaptation and disaster resilience funding, to ensure its long-term viability.

8.3 Summary of key responses

Table 8.1 summarizes the key actions proposed under each of the five thematic areas addressed under Pillar V, spanning both national and international levels.

Table 8.1 Summary of key actions to enhance data governance

Focus area	Key actions
Developing foundational ICT infrastructure	• Invest in modern, cost-effective environmental monitoring equipment, including IoT-enabled sensors and remote sensing tools. • Expand broadband, mobile and satellite connectivity in underserved regions, prioritizing remote monitoring areas.

	• Support the deployment of edge computing to reduce reliance on high-speed centralized infrastructure. • Build interoperable national and regional data hubs for storing and processing large-scale datasets. • Map infrastructure gaps to identify investment priorities and coordinate multi-stakeholder solutions.
Ensuring access to data management and processing resources	• Facilitate institutional access to cloud and hybrid storage systems through public subsidies and policy incentives. • Promote open-source, low-cost data management frameworks to reduce vendor lock-in. • Enable adoption of high-performance cloud platforms by negotiating non-commercial access for public institutions. • Promote coordination in tool development through international working groups and shared standards. • Fund modular, interoperable tools optimized for low-bandwidth environments and regional contexts. • Create shared repositories and transparency standards for open-source analytical tools.
Building needed skills and knowledge	• Embed environmental data training in university programs and technical institutes, with scholarships for underrepresented regions. • Create multilingual, open-access digital learning platforms covering the full data pipeline. • Develop agile, modular training programs to adapt to fast-evolving technologies. • Establish regional knowledge hubs to provide tailored technical assistance and peer-to-peer learning. • Partner with tech firms to offer fellowships and mentorships in cloud computing, AI, and geospatial analysis. • Support AI literacy and ethics training for policymakers and regulators. • Develop public-private training programs to build ESG and sustainability reporting capacities across sectors.
Strengthening institutional capacities	• Create dedicated interdepartmental units to coordinate environmental data across government. • Professionalize data management: establish clear career pathways, salary incentives, and training for data specialists in public institutions. • Combine open government commitments with integrated data platforms for evidence-based policy. • Design real-time dashboards and tools that link environmental data with planning and governance functions.

	• Formalize public–private coordination through advisory panels and working groups to align regulatory frameworks and reporting standards.
Securing sustainable funding for data governance	• Mainstream environmental data governance in national development budgets and legislative mandates. • Leverage global climate and development finance (e.g. Global Environment Facility, Green Climate Fund) for long-term environmental monitoring investments. • Explore new funding mechanisms including data subscriptions, green bonds, and environmental data services. • Establish multi-year funding streams for data maintenance, storage, and institutional continuity. • Engage philanthropic and private sector partners to co-finance infrastructure and capacity development, particularly in low-income countries.

8.4 Overview of best practices in Pillar V

Example	Section
SPREP's regional data repository enhances accessibility and reduces storage costs in the Pacific region.	5.2.1 Developing foundational ICT infrastructure
DestinE is building a federated digital twin of the planet, offering a model for interoperable data systems using shared infrastructure and common standards.	5.2.1 Developing foundational ICT infrastructure
EOSC and OpenAIRE facilitate the sharing and reuse of analytical tools across multiple institutions.	5.2.2 Ensuring access to data management and processing resources
FAO's SEPAL system provides cloud-based geospatial analysis tools to support forest monitoring and climate reporting in developing countries	5.2.2 Ensuring access to data management and processing resources
Digital Earth Africa uses Open Data Cube technology to provide African nations with access to EO data for agriculture, water monitoring, and urban planning.	5.2.2 Ensuring access to data management and processing resources
Open source learning platforms such as "AI for Earth" and NASA's ARSET democratize knowledge and offer structured training.	5.2.3 Building needed skills and knowledge
SPREP regional knowledge hubs provide training, technical assistance, and tailored e-learning platforms.	5.2.3 Building needed skills and knowledge
IPBES helps users recreate data processes and track provenance through its data management report and capacity-building programmes	5.2.3 Building needed skills and knowledge

World Bank's Digital Earth Partnership bridges data supply and demand, connecting tech firms with policymakers.	5.2.3 Building needed skills and knowledge
ODC and WB's Open Government Data Toolkit promote open data as a guiding principle for environmental strategies.	5.2.4 Strengthening institutional capacities
France's coordinating body in the PM's office drives forward environmental data governance across government.	5.2.4 Strengthening institutional capacities
ESA Fellowships provide structured career pathways for young professionals in Earth observation and remote sensing.	5.2.4 Strengthening institutional capacities
UNEP FI and the Life Cycle Initiative support capacity-building for environmental disclosures and LCA data systems, helping institutions strengthen reporting and oversight.	5.2.4 Strengthening institutional capacities
Net Zero Data Public Utility: a public–private data partnership providing open, standardized company-level GHG data to improve climate transparency and disclosure.	5.2.4 Strengthening institutional capacities
EU/Finnfund Africa Connected Programme: a public-private partnership focused on improving ICT infrastructure and reducing cost barriers in developing regions.	5.2.5 Securing sustainable funding for data governance

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Annex IV Indicative listing of environmental data sources and formats

Table IV.1 Illustrative list of environmental data sources

Source type	Description	Relevant data domains
Earth observation (remote sensing)	Satellite-based systems that capture imagery and spectral data on Earth's surface and atmosphere	Geospatial and land use data; climate and weather data; water and ocean data
In situ monitoring (sensors, stations)	Ground-based sensors and monitoring stations recording environmental variables	Pollution and emissions data; water and ocean data; climate and weather data
Administrative and official reporting	Government data from agencies, national statistical offices and mandated reporting processes	Socioeconomic, demographic and economic driver data; policy, legal and governance data; pollution and emissions data
Scientific research and academic data	Data collected and shared through peer-reviewed studies, research projects and university labs	Biodiversity and ecosystem data; environmental impacts on people and ecosystems; innovation, technology and solutions data
Corporate disclosures and reporting	Company-provided data on environmental impacts, ESG indicators, supply chains and product footprints	Corporate and product-level data; pollution and emissions data; resource use and sectoral activity data
Crowdsourcing and citizen science	Data generated by individuals or communities using apps, sensors or reporting platforms	Biodiversity and ecosystem data; environmental impacts on people and ecosystems; geospatial and land use data
Indigenous and community-based monitoring	Observations and knowledge systems rooted in local and traditional practices	Biodiversity and ecosystem data; environmental impacts on people and ecosystems
Modelled and inferred data	Data estimated using models, interpolation, AI/ML or scenario projections	Climate and weather data; environmental impacts on people and ecosystems; hazards, risk and resilience data
Geospatial and cadastral data	Maps and spatial datasets related to land tenure, boundaries, infrastructure and planning	Geospatial and land use data; policy, legal and governance data
Web and digital trace data	Data extracted from internet activity, social media, mobile apps and digital platforms	Socioeconomic, demographic and economic driver data; environmental impacts on people and ecosystems; innovation, technology and solutions data

Table IV.2 Illustrative list of environmental data formats

Format	Full name	Role and examples
Tabular and statistical data		
CSV	Comma-separated values	Standard for statistical tables, time series, emissions inventories, socioeconomic data
Parquet	Apache Parquet	Efficient columnar format for large datasets in analytics, AI/ML pipelines and dashboards
SDMX	Statistical Data and Metadata eXchange	Format for structured statistical indicators and metadata (e.g. SDGs, national reporting)
XLSX	Excel spreadsheet	Government and corporate data spreadsheets; financial reports; environmental statistics
Geospatial vector and raster data		
GDB	Geodatabase	ESRI geodatabases for complex spatial datasets and layers
GPKG	GeoPackage	Open format for storing vector and raster geospatial data; modern alternative to shapefile
GeoJSON	Geospatial JSON	Web-friendly spatial vector data (e.g. boundaries, participatory maps)
GeoTIFF	Georeferenced Tagged Image File Format	Raster maps from remote sensing (e.g. land cover, NDVI, risk zones)
KML	Keyhole Markup Language	Used for lightweight geospatial overlays, especially in participatory and mobile mapping tools
SHP	Shapefile	Traditional GIS vector data for land use, species, infrastructure
Scientific and gridded model data		
GRIB	Gridded Binary	Widely used in meteorological data for weather forecasts and reanalysis models
HDF5	Hierarchical Data Format version 5	High-volume scientific model data, alternative to NetCDF
NetCDF	Network Common Data Form	Gridded environmental data from models (e.g. climate, oceans)
XML	Extensible Markup Language	Used in structured environmental reporting and metadata exchange (e.g. EPRTR, INSPIRE)
Linked data and web exchange		
HTML	HyperText Markup Language	Web-based data portals, dashboards, interactive tools

JSON	JavaScript Object Notation	API outputs, sensor feeds, dynamic dashboards, citizen data
JSON-LD	JSON for Linking Data	Semantic metadata and linked open data (LOD); registries
WMS / WFS	Web Map Service / Web Feature Service	Protocols for accessing geospatial layers over the web; used in real-time monitoring and dashboards
Document and reporting formats		
ILCD	International Life Cycle Data system	EU standard format for LCA and environmental footprinting
PDF	Portable Document Format	Policy documents, ESG reports, scientific papers, legal texts
ecoSpold	Ecological Spold format	Lifecycle assessment (LCA) models; product-level environmental data

Annex V UNEP inventory of environmental data platforms

In preparing GEDS, UNEP conducted an inventory of publicly available environmental data sources and platforms. As of March 2025, a review of over 650 environmental data platforms identified 464 platforms that directly align with the three pillars of the UNEP Medium-Term Strategy: climate change, nature loss and pollution. The majority of these platforms contribute to multiple MTS pillars, with the strongest representation in climate change, biodiversity/wildife and water. However, many platforms primarily function as data repositories rather than offering advanced analytical interfaces.

Of the platforms reviewed, 156 provide APIs, facilitating data access and integration, while 116 were recognized as best practices, characterized by comprehensive documentation, API availability, and robust analytical tools.

The inventory can be viewed online at:
https://airtable.com/appOImrs9TVF2MA2e/shrPbbNacnNtt3nBE/tblBSY70KB5nGDuGc