UNEP Global Environmental Data Strategy

Full strategy document

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Summary

High-quality, accessible and interoperable environmental data are essential for addressing the world's most pressing environmental and sustainability challenges. Yet the global environmental data ecosystem that exists today is characterized by major gaps in data availability, accessibility and quality. Many countries lack the skills, knowledge, infrastructures and tools to collect, analyse and use environmental data to guide policy and action. Even where data are collected, the incoherence of the global system means that their value is often squandered. The lack of interoperability makes it hard to integrate datasets and uncover critical connections between climate change, ecosystem degradation and global challenges such as security, migration and disease. Without a more cohesive and accessible data ecosystem, governments and societies will struggle to extract meaningful insights and implement effective responses.

Recognizing the need for stronger global action on environmental data governance, the United Nations Environmental Assembly (UNEA) adopted resolution 4/23 in 2019. It thereby requested the UNEP Executive Director to develop and prioritize a long-term data strategy in consultation with governments, UN partners, international and regional scientific bodies and others. Since 2020, UNEP has invested in a series of reports and multi-stakeholder consultations to build a deep understanding of the global environmental data ecosystem as it exists today and a shared vision for effective environmental data governance in the future. Those efforts, described in more detail in Chapter 1 and the Annex, have culminated in the present strategy.

The Global Environmental Data Strategy (GEDS) aims to provide Member States and other stakeholders with a comprehensive outline of the challenges and disfunctions in the environmental data ecosystem from local to global scales, as well as outlining potential responses, existing best practices and recommendations for next steps. These recommendations include a variety of potential actions that UNEP could take to support the transformation of the global environmental data ecosystem. The analysis presented here is necessarily lengthy and this "full strategy document" will therefore be complemented with a shorter "synthesis" that captures the key findings and conclusions.

The five pillars of GEDS

To structure its analysis and recommendations, GEDS is organized around five priority pillars, which were identified through the research and stakeholder consultation processes in 2023-2024.

- **Pillar I – Data governance** encompasses the overarching framework of policies, institutions, principles and practices that define how environmental data is collected, shared and used. This includes measures to ensure fair, ethical and secure data management.
- **Pillar II – Data quality and provenance** addresses the tools and approaches needed to ensure that the global environmental data ecosystem produces sufficient good quality data to meet the needs of governments, businesses and other stakeholders**.**
- **Pillar III – Interoperability** focuses on ensuring that environmental data from different sources can be easily integrated, compared and used across locations and institutions. This includes harmonizing data formats, protocols and standards, balancing standardization with flexibility.

- **Pillar IV – Accessibility and affordability** addresses the financial, technical and institutional barriers that prevent stakeholders from finding, accessing and using environmental data. This includes navigating concerns about sensitive data and developing open, user-oriented platforms.

- **Pillar V – Capacity-building** focuses on the need to strengthen infrastructure, expertise and institutional frameworks to ensure that all stakeholders, including in low-income countries, can manage and use environmental data effectively.

Chapters 2-6 of the present document explore each of these pillars, presenting a vision for a desirable future state and then mapping out the challenges with the system today and opportunities to respond, including examples of best practices. As outlined in brief in Table 1, the analysis points to a diverse array of needed actions in each pillar. In many cases, however, these interventions would involve building on and connecting the initiatives that are already emerging in specific environmental domains or regions.

Priority UNEP actions to initiate implementation of GEDS

Chapters 2-6 also include ideas about potential UNEP actions that could facilitate an effective global response. These have been synthesized into five clusters of potential UNEP actions in Chapter 7, which can guide the development of UNEP's next medium-term strategy (2026-2029) and programmes of work.

A selection of those actions stand out as key priorities. In some cases these actions would require mandates and financial resources to implement. They are therefore presented here for Member State consideration and possible action at the 7th session of the UN Environment Assembly.

1. **Promote GEDS principles through continued development of the World Environmental Situation Room (WESR)** as a UNEP data and applications platform supporting decision-making and action. WESR should integrate data from a variety of sources, including UNEP projects, third-party data platforms, governments and civil society organizations. It should include tools to analyse and visualize multiple datasets to allow exploration, exposition and storytelling. WESR should implement rigorous data quality standards and ensure a robust data governance framework to maintain its reliability and credibility and safeguard UNEP's reputation as a trusted and authoritative source of information.

2. **Promote uptake of GEDS principles at country level through pilot projects**, such as the current UNEP-GIZ project, "Capacity and use case development for environmental data-driven value creation and innovation", which strengthens data partnerships, exchange and national capacities in the East Africa region. By promoting integration of data across scales and creating digital public goods, the project aims to drive innovation and sustainable economic growth, advancing the SDGs.

3. **Create a Global Environmental Data Governance and Classification Framework** to guide countries in developing national environmental data strategies and policies. Building on existing data governance frameworks at national level, the framework would set out environmental data governance principles, data classification frameworks, and technical and interoperability standards. It would serve as a baseline of best practices and recommendations, allowing UNEP to work with Member States to customize and implement it within national contexts.

Table 1 Overview of global responses outlined in GEDS Pillars I-V

Pillar I: Data governance	**Guaranteeing data sovereignty and security**, e.g. through federated governance models, guidelines and rules on cultural protocols, and cybersecurity measures.	**Coordinating global environmental data governance**, e.g. by clarifying mandates and aligning national and global governance frameworks to reduce fragmentation.	**Tackling inequities, power imbalances and ethical issues**, e.g. by ensuring participation, respecting Indigenous data sovereignty, empowering marginalized groups.	**Ensuring effective data stewardship and managing data overload**, e.g. by identifying priority data and building sustainable and interoperable infrastructure.	**Integrating businesses and finance into environmental data governance**, e.g. by developing business-friendly tools, promoting transparency and harmonizing reporting.	
Pillar II: Data quality and provenance	**Addressing gaps, inaccuracy and biases in environmental datasets** e.g. through data auditing, leveraging AI and using EO and citizen science to validate and triangulate.	**Strengthening standards on data collection, processing and QA**, e.g. establishing quality standards and clearing houses and implementing data quality frameworks.	**Ensuring transparency and provenance tracking**, e.g. by implementing provenance standards, automating provenance data collection and using digital identifiers.	**Preserving confidence and trust in environmental data**, e.g. by certifying datasets and high quality repositories, and integrating indigenous and local knowledge.	**Aligning data generation with decision-making needs**, e.g. identifying priority dataflows, shifting academic incentives and leveraging Digital Product Info Systems.	**Responding to the need for integrated data and assessments**, e.g. by breaking down silos and linking environmental datasets with data on human health, well-being, justice, etc.
Pillar III: Interoperability	**Harmonizing data formats, standards and semantics**, e.g. by defining minimum metadata standards and adopting standardized vocabularies and ontologies.	**Promoting workflow interoperability, documentation and linked data**, e.g. by publishing full workflow information and establishing linked data frameworks.	**Enhancing API infrastructure**, e.g. by mandating use of APIs in public platforms and monitoring frameworks, using open APIs, and documenting and indexing APIs.	**Balancing harmonization and flexibility in interoperability protocols**, e.g. by facilitating agreement on minimal but widely accepted standards.	**Navigating proprietary software and closed data ecosystems**, e.g. investing in publicly funded platforms and open-source software and promoting cloud interoperability.	**Leveraging AI to improve interoperability**, e.g. by building institutional readiness, committing needed resources, and strengthening legal and ethical frameworks.
Pillar IV: Accessibility and affordability	**Ensuring repositories are findable and accessible**, e.g. by improving cataloguing systems, digitizing legacy data, and developing long-term preservation strategies.	**Reducing cost barriers to data access**, e.g. by expanding open access to publicly funded data, incentivizing data sharing and creating tiered data access models that help offset costs.	**Balancing access against concerns about strategic and sensitive data**, e.g. by developing tools to guide licensing decisions, and agreeing international data sharing protocols.	**Navigating commercial interests and cloud dependency**, e.g. by strengthening corporate reporting, promoting data trusts, and licensing commercial use of public data.	**Creating user-oriented data platforms**, e.g. by creating decision-ready insights, using intuitive visualizations and analysis tools and engaging with users to improve platforms.	
Pillar V: Capacity-building	**Developing foundational ICT infrastructure**, e.g. by investing in monitoring and connectivity, and strengthening data storage and processing capacity.	**Ensuring access to data management and processing resources**, e.g. by expanding access to low-cost cloud storage, processing and tools, and coordinating development of tools.	**Building needed skills and knowledge**, e.g. by creating learning platforms and regional knowledge hubs, and developing public private partnerships and talent pipelines.	**Strengthening institutional capacities and legal frameworks**, e.g. by developing national data strategies, and creating dedicated implementation units and career pipelines.	**Securing sustainable funding for data governance**, e.g. by integrating environmental data governance into national budgets and mobilizing external funders.	

4. **Develop and implement a tiered capacity-building framework** that identifies and responds to the needs of individual countries and organizations. Based on capacity assessments, UNEP would develop courses, guidance documents and adaptable decision-support tools. It would also facilitate the exchange of relevant knowledge and best practices via regional hubs and peer learning networks, and an online exchange platform to collect and share best practices.

5. **Lead a process to identify a global core set of environmental indicators** in order to simplify reporting processes, focus investments in data collection, align data across countries and domains, and generate robust inputs to assessments and policymaking. This would need to align with existing reporting frameworks and build on initiatives such as the UNECE core set of environmental indicators.

6. **Convene an Expert Group on Interoperability Standards** to work to harmonize data formats, metadata structures, API protocols and semantic classifications to ensure that environmental datasets from different sources can be combined and used for global monitoring, policy and decision-making. The group could include all relevant stakeholders and build on existing initiatives led by, for example, CODATA, GEO, GBIF and WMO as well as standards bodies like ISO, OGC and ITU.

7. **Establish a global clearinghouse for environmental data quality** to help build trust in environmental data, encourage best practices in data collection and management, and provide governments, researchers and businesses with a clear framework for assessing data reliability. This would necessarily need to take a pragmatic approach to avoid creating an overload of work. For example, UNEP could convene an expert group to develop a classification system. Data providers seeking a UNEP-backed "stamp of approval" would have the option to voluntarily submit their datasets to the expert groups for evaluation against these standardized criteria.

8. **Explore options for a Global Environmental Data Utility** to provide equitable access to a wide range of environmental data under a shared policy framework. The utility would serve as a centralized access point, ensuring that developing countries can obtain critical datasets for free or at low cost. To sustain this model, a long-term funding mechanism would be required to compensate or subsidize data providers, ensuring continued accessibility and reliability.

9. **Develop a strategic approach to support MEAs in enhancing data collection and reporting processes**, enabling more effective contributions to the global environmental data ecosystem. UNEP could work with MEA secretariats and national focal points to identify opportunities for harmonized and modular digital reporting systems and tools that simplify reporting. UNEP could also engage with funding bodies such as GEF and GCF about assisting countries in transitioning to digitized, standardized reporting systems as part of MEA enabling activities.

Member States are invited to consider these priority actions and explore other potential avenues for implementing the actions proposed across Pillars I-V. Strengthening global environmental data governance will require sustained collaboration, investment and innovation. UNEP stands ready to support Member States in achieving the vision of "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".

1 Context and strategic foundations

1.1 The need for a Global Environmental Data Strategy

The world today faces rapidly growing and interconnected environmental crises. Innovative digital advances, driven by diverse sources of data, are emerging as powerful tools to address these unprecedented challenges. In some environmental domains and regions, efforts are under way to create more harmonized and usable environmental data ecosystems. Yet, the world still faces major challenges in using environmental data for decision-making due to the fragmentation of the environmental data ecosystem, problems merging and using data that are not interoperable, and physical, financial and capacity-related barriers to accessing needed data.

Based on a review of approximately 500 global environmental data resources, UNEP has found that most resources are data repositories that lack an analytical interface (Figure 1). In many cases, these resources are difficult to access or use effectively. Less than one third of the resources reviewed have Application Programme Interfaces (APIs) in place to enable automated data exchange (Figure 2). In 14% of cases, the data are not even downloadable. Moreover, even in instances where data are fully accessible, the proliferation of different data standards within and across environmental domains means that data often cannot be combined or taken up in analysis. In most cases, the data originates from multiple sources. However, each dataset has its own separate documentation, update frequency, and temporal and geographic coverage, making it challenging to gain an overview of the available data and its characteristics on different platforms.

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)

Figure 1 Data resource types identified

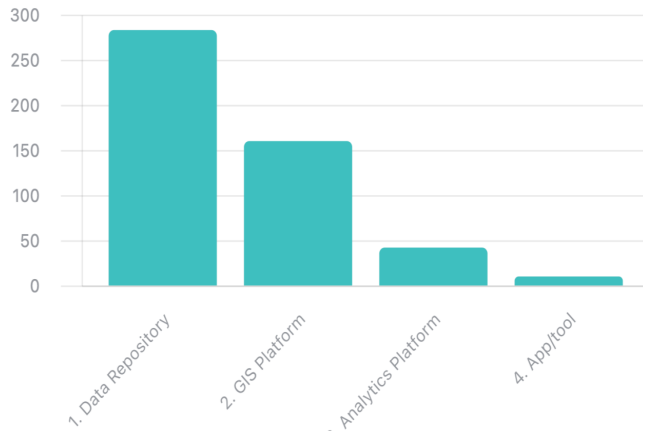
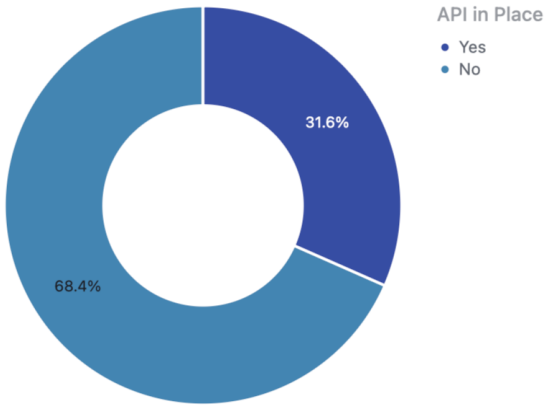


Figure 2 APIs in place



Many governments are already taking steps to drive forwards digital transformation in their countries but such measures will not be enough to create a functioning global environmental data ecosystem. Environmental problems are often highly interconnected and transboundary in nature, requiring coordinated action at regional or global scales to achieve results. Moreover, coordination is made difficult by the distinctive characteristics of environmental data (Jensen and Nachmany, 2020). These include the importance 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. Access to environmental data also underpins the human right to a "clean, healthy and sustainable environment", as articulated in UN General Assembly resolution A/76/L.75 (UNGA, 2022) and the Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (UN, 1998).

Recognizing the need for stronger global action on environmental data governance, the United Nations Environmental Assembly (UNEA), at its fourth session held in March 2019, adopted resolution 4/23 entitled "Keeping the world environment under review: enhancing the United Nations Environment Programme science-policy interface and endorsement of the Global Environment Outlook" (UNEP, 2019b). It requested the Executive Director of UNEP to develop and prioritize a long-term data strategy within the programme of work and budget, "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".

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).

Based on this mandate, the overarching goal of the Global Environmental Data Strategy (GEDS) is to ensure that timely and trustworthy environmental data are available for use at all levels of governance to achieve a more sustainable world.

The development of GEDS is aligned with UNEP's broader activities promoting digital transformation, which encompasses action to advance big data analytics, cloud computing and artificial intelligence (AI) in order to bolster 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, 2023b), which together aim to ensure that environmental assessments, monitoring, reporting and decision-making are supported by robust, accessible and reliable data.

Box 1 Defining "environmental data"

In developing the Global Environmental Data Strategy, UNEP has defined environmental data as:

Data that encompasses the measurement of environmental indicators related to pressures and drivers of degradation, the state of the environment, the impacts on ecosystems and society, and potential solutions to address and mitigate these impacts.

Environmental data are based on a broad range of sources and measurement techniques, including Earth observation, drones, IOT sensors, ground monitoring stations, academic research, business reporting, crowdsourcing, communities and indigenous groups, and citizen science. 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.

1.2 Context for GEDS: a fast changing data governance landscape

The development and future implementation of GEDS is taking place in a rapidly shifting context. The pace and scale of changes in technologies, business models and user expectations necessitate major changes in global environmental data governance.

Misinformation, echo chambers and filter bubbles: Rapidly increasing global connectivity and uptake of digital technologies has led to an overload of information, making it hard to differentiate credible sources. Misinformation spreads quickly, with echo chambers and filter bubbles reinforcing existing biases, driving polarization and undermining decision-making. Collectively, these trends pose major governance challenges, making it hard to ensure access to reliable and high quality environmental data.

The rapid advance of artificial intelligence: AI is driving major shifts in needs, expectations, applications and risks. It has the potential to enhance environmental modelling, cross-domain analysis and digital twins, while offering new opportunities for data-driven decision-making. But it also creates substantial risks, such as biases in data interpretation, amplification of misinformation, concerns about the transparency of algorithms and growing environmental impacts from energy-intensive computing. The simplicity of many AI tools, such as Chat-GPT, is also starting to influence end-user expectations. In particular, there is a rising expectation that accessing and analysing environmental data should be possible using simple natural language queries.

New sources of data: Rapid innovation is also expanding the availability and diversity of environmental data. Drones, satellites, low-cost sensors, edge computing and the Internet of Things could revolutionize environmental monitoring, enabling continuous, real-time data collection. Citizen science has the potential to become a powerful tool. The widespread accessibility of smartphones offers opportunities to capture localized information at unprecedented scales. However, the need to ensure quality control and trustworthiness remains a key challenge.

Shifting user expectations: Users increasingly demand streamlined, user-friendly tools offering actionable solutions. Near real-time data is increasingly seen as essential for maintaining societal resilience, for example in supporting agile decision-making, early warning systems and disaster response. Data providers are likewise putting stronger emphasis on human-centered design. Instead of one-size-fits-all solutions, modern platforms offer increasing customization, including direct access to raw data.

Structural changes and concentrations of power: Data ecosystems are becoming both more decentralized and more interconnected, with APIs and federated data systems enabling data sharing and integration, while preserving local data sovereignty and navigating privacy and security concerns. At the same time, there is a growing concentration of digital capacities in the private sector, with a small number of very large technology companies controlling a substantial proportion of the world's global digital public

infrastructure, public data catalogues and data science expertise. This creates challenges and dependencies for public sector actors, driving greater reliance on public-private partnerships.

Integration of environmental, social and economic data: The environmental, social and economic data ecosystems are increasingly interconnected as environment and climate goals become integral to national accounts, social protection and public health, and corporate financial reporting. Digital Product Information Systems are being introduced (e.g. in China, the EU, Japan and South Korea), generating significant volumes of environmental performance data that can be used to guide consumer choices and green procurement. Environmental data are similarly integral to financial risk assessments and disclosures frameworks such as the International Sustainability Standards Board sustainability disclosure standards, which implement the recommendations of the Task Force on Climate-related Financial Disclosures (IFRS, 2025b). Environmental provisions in international trade policy and bilateral investment treaties are increasingly a driver for environmental data. And donors are also demanding growing levels of transparency to understand the environmental, social and economic impacts of their programmes. The proliferation of data sources creates a pressing need for tools that can help end users integrate and make sense of all the data.

Governance principles: In a context of pressing governance challenges, there is growing recognition of the need for effective principles and mechanisms to ensure that the global environmental data ecosystem operates ethically and sustainably, responding to the data needs of global society. Frameworks such as FAIR (findable, accessible, interoperable, reusable), CARE (collective benefit, authority to control, responsibility, ethics) and TRUST (transparency, responsibility, user focus, sustainability, technology) are gaining traction. The environmental footprint of data collection, processing and storage is also under scrutiny. Innovations in low-energy systems and green data practices are becoming critical for sustainability.

1.3 Development of GEDS

1.3.1 Guiding vision and principles

UNEP's vision is 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.*

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 also guaranteeing that countries can retain control over their own data, including deciding what is shared and who has access.

GEDS seeks to create a broad framework for working towards a better global environmental data ecosystem, framing the development of more focused strategies and programmes by UNEP and its

partners at international and national partners. As such, GEDS is not about creating a huge data repository but it could be an enabler for creating distributed, federated data repositories at national, regional or global levels. Similarly, it does not propose developing and imposing new data formats, standards and protocols but it could trigger global discussions to find ways to harmonize and simplify the fragmented patchwork that exists today. Finally, GEDS aims to support, connect and build on existing regional and domain-specific data strategies, rather than replacing them.

1.3.2 Process

Since 2020, UNEP has invested in a series of reports and ad hoc multi-stakeholder consultation processes with the aim of building a deep understanding of user needs and the characteristics of the global environmental data ecosystem, including existing platforms, data sources and standards.

As set out in more detail in Annex, the analytical work has included developing a UNEP roadmap on environment statistics, accounting and analysis (2021); exploratory analysis and research for the GEDS conceptual framework (2022-2023); an inventory of UNEP data platforms and APIs (2023); a preliminary mapping of existing environmental data standards globally (2023); a survey of environmental data consumers and producers across UNEP (2023); and an inventory of more than 800 external environmental data platforms. Preliminary stakeholder engagement and feedback sessions were also hosted in multiple forums, including the UN Round Table on Digital Public Goods (2020); the Coalition for Digital Environmental Sustainability (2022); the UN Science Policy Business Forum (2023), the UN Framework Convention on Climate Change COP28 meeting (2024), the UN Environment Assembly Digital Accelerator Lab (2024) and the UN High-Level Political Forum on Sustainable Development (2024).

GEDS has also been developed in the context of the UN Secretary-General's Data Strategy (UNSG, 2020) and in coordination with various ongoing processes and initiatives within the UN system. These include, for example, the international data governance work of the UN's High-Level Committee on Programmes (UN, 2023) and the data strategies being developed by partners such as the UN Conference on Trade and Development (UNCTAD), the United Nations Educational, Scientific and Cultural Organization (UNESCO) the World Health Organization (WHO) and the World Meteorological Organization (WMO). Additionally, GEDS aligns with the Global Digital Compact (GDC), reinforcing the need for transparent, inclusive and interoperable environmental data governance as part of broader efforts to enhance global digital cooperation. GEDS is particularly relevant to GDC Objective 7 (4) on advancing "responsible, equitable and interoperable data governance approaches"; Principle 8 (g) on the need for "accessible and affordable data and digital technologies and services … to enable every person to participate fully in the digital world"; and Commitment 17 (b) on promoting "the adoption of open standards and interoperability to facilitate the use of digital public goods across different platforms and systems (all SDGs)".

Based on the initial research and consultations, and the data gaps and challenges identified, UNEP established a framework for the Global Environmental Data Strategy with five key pillars:

- **Improving data governance:** The framework of policies, institutions, principles and practices that provide a foundation for the other pillars, ensuring ethical, effective and sustainable environmental data management practices.

- **Data quality and provenance:** Tools and approaches to ensure that the global environmental data ecosystem is producing sufficient good quality data to meet the needs of governments, businesses and other stakeholders.
- **Data interoperability**: Mechanisms and actions to combine and integrate the diverse and fragmented datasets - across domains, regions and platforms - that together make up the global environmental data ecosystem.
- **Data access and affordability**: Actions to ensure that all stakeholders can access and afford the environmental data needed to support sustainable development, while also navigating concerns about sensitive data and security.
- **Capacity-building**: Measures to help countries develop the broad range of skills, knowledge, tools and infrastructures that are needed to collect, process, share, communicate and use data in policymaking processes and reporting on progress against environmental goals.

Figure 3 Five core pillars of the Global Environmental Data Strategy

1.3.3 Structure

The structure of the remainder of this strategy document follows the five pillar structure set out above. Chapters 2-6 describe the key challenges in each pillar, the responses needed by governments and other stakeholders to address them, and potential UNEP actions following from GEDS. Chapter 7 integrates the various UNEP actions outlined across Pillars I-V into a synthesis and identifies a set of priority actions for consideration by Member States.

2 Pillar I: Data governance

2.1 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; and data stewardship – both managing the environmental burden of data storage and processing, and prioritization of certain data streams.

A 10-year vision for data governance

In 2035, we have a well-functioning global environmental data governance system, which guarantees data sovereignty, while enabling seamless collaboration across borders and sectors.

This system is inclusive, equitable and empowers vulnerable communities, fostering secure, ethical and transparent data practices.

It is also responsive to the needs of all stakeholders to make data-driven decisions to support sustainable development. It prioritizes critical indicators and integrates environmental data into policy and business strategies for a resilient future.

2.2 Key challenges and potential responses

2.2.1 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 threats: Environmental data platforms face growing cyber threats, including hacking, data corruption and unauthorized access, which undermine trust and discourage data sharing. Privacy concerns and the risk of data breaches can hinder implementation of environmental policies and measures and could make some governments hesitant to participate in global environmental data initiatives.

Responses

A fair and viable global environmental data ecosystem can only be achieved if countries, Indigenous groups 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.

Strengthening national data sovereignty while enabling collaboration: All countries should be able to govern their own environmental data. That means having control over issues such as what is published, what is shared, what is accessible to which actors and when information is deleted. Countries should be given support to build and maintain their own datasets and preserve their sovereignty. At the same time, 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. The goal should be to enable controlled international access while preserving national and community rights over environmental data.

Creating a federated environmental data ecosystem: In practice, sharing of national environmental data should follow a federated governance model. This would enable countries to own and process their own data but make indicators and (where appropriate) datasets and methods available in central federated spaces. The UNEP World Environmental Situation Room could provide one such space.

Guidelines and rules to respect cultural protocols and Indigenous data sovereignty: In line with the UN Declaration of the Rights of Indigenous Peoples (UNGA, 2007) and the CARE Principles for Indigenous Data Governance (Carroll et al., 2020), developing context-specific guidelines for research and data collection that respect local cultural protocols is vitally important to ensure that practices are culturally sensitive and ethically sound. Legal and policy frameworks are also needed to ensure that Indigenous communities retain control over data originating from their lands, resources and cultural practices. Developing models that offer communities reciprocal benefits (e.g. technical support or financial compensation) for communities that share data for commercial use can further help mitigate data colonialism and exploitation.

Box 2 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 trust in environmental data platforms: Environmental initiatives and data sharing can be enabled through stronger cybersecurity measures. This could include developing global cybersecurity protocols tailored to environmental data and implementing end-to-end encryption and secure APIs to facilitate safe and controlled data sharing across jurisdictions. AI can also be used to enhance data security by monitoring access, detecting anomalies and preventing unauthorized activities.

Potential UNEP actions following from GEDS

Convening stakeholders to build shared understanding

- Engaging countries and other stakeholders in developing an international agreement on environmental data sovereignty, drawing on frameworks such as the Aarhus Convention on environmental information access (UN, 1998). Such an agreement 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.
- Working with governments, international organizations and Indigenous groups to develop data classification frameworks that help guide which data can be shared and how.
- Implementing GEDS through a process of continuing dialogue with stakeholders to develop a more granular understanding of their technical realities and governance needs on the ground. For example, organizing regional dialogues and technical roundtables, ensuring engagement from Indigenous communities and low-income countries, and implementing pilot projects.

Advocacy

- Advocating for federated data-sharing mechanisms, based on sound data classification methodologies, where nations and stakeholders maintain local control but enable structured cross-border sharing through APIs and common standards.

Developing tools for secure data sharing

- Positioning the World Environment Situation Room (WESR) as a federated hub, which catalogues selected data or metadata from different sources, allowing data providers to maintain ownership and control while ensuring discoverability (see also Pillar III on interoperability).

2.2.2 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, multilateral environmental agreements, 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.

Overlapping and outdated international reporting processes: International organizations and institutions, including multilateral environmental agreements, often operate independently, leading to inconsistent policies, data silos and inefficiencies. Countries must report the same data multiple times using different formats, structures and data standards. This creates an unnecessary burden and makes it hard to aggregate the data at a global level, reducing transparency and accountability. With few exceptions (e.g. the Minamata Convention and the Convention on Biological Diversity), MEAs lack robust data standards and digital reporting platforms to help Member State harmonize reporting such that reported data can be aggregated from national to global level. Many national reporting processes still use PDF documents, which restrict accessibility and prevent easy aggregation and analysis.

While UNEP's InforMEA initiative has made important progress in creating an integrated and accessible knowledge base on multilateral environmental agreements and related national laws and reports, it does not aggregate national reporting data. Meanwhile, individual MEAs may lack the mandates, incentives and resources to change their reporting processes to increase harmonization and streamlining.

Responses

In broad terms, creating a more coordinated system of global environmental data governance requires a deep understanding of the global environmental data ecosystem and how it is changing over time; identification of priority actions to improve coordination; and the development of flexible structures and tools that can guide and sustain incremental improvements in global environmental data governance.

Connecting existing initiatives: In the short term, the focus would likely be on building 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. Linking to initiatives that provide environmental concentration and public health data, such as NHANES (linking pollution exposure to human health impacts) would strengthen cross-sectoral linkages.

Streamlining environmental data reporting processes: There are opportunities to simplify and improve national data reporting obligations in relation to MEAs and other agreements such as the SDGs, and create a more integrated evidence base for policy and action. Possible steps could include, for example, harmonizing data collection and reporting policies, aligning data and metadata standards and creating a single digital platform for data submission. Some MEAs such as the Minamata, Basel and Stockholm Conventions, have introduced online reporting systems, while UNEP's DaRT reporting tool supports national reporting to biodiversity-related conventions.

Other examples of good practice include the Norwegian Institute for Air Research (NILU), which oversees data management for several key international programmes. These include UNECE's Convention on Long-Range Transboundary Air Pollution (UNECE, 1979), the World Meteorological Organization's Global Atmosphere Watch (WMO, 2025) and regional frameworks such as OSPAR, HELCOM and AMAP. Solutions such as national contact points, clearinghouses and centralized data repositories can promote reliable and harmonized data delivery. It is important note, however, that achieving alignment between MEAs would need to be based on careful analysis of overlaps and inconsistencies, and actions to align data collection and reporting would need to be agreed by the relevant governing bodies.

Potential UNEP actions following from GEDS

Mapping and analyzing opportunities for harmonization

- Conduct a comprehensive analysis of overlaps and inconsistencies in data reporting requirements for MEAs, SDGs and other agreements, identifying opportunities for standardization and alignment to reduce duplication and improve data consistency.
- Develop best practice guidelines on data collection, reporting and management for MEA secretariats, drawing on UNEP's experience in environmental data governance.

Convening stakeholders

- Facilitate stakeholder deliberations including MEA secretariats to develop solutions for streamlining reporting processes.
- Work with MEA secretariats to align data and metadata formats and standards, ensuring interoperability between different reporting mechanisms.

Developing reporting tools

- Support the creation of modular reporting templates that countries can use across multiple MEAs, simplifying data submission.

- Support the development of a shared digital platform that allows for the submission, validation and integration of MEA data in a standardized format.
- Explore how UNEP platforms, such as the World Environment Situation Room (WESR), could support data sharing and aggregation for MEAs.
- Provide capacity-building and technical assistance to MEA focal points and national reporting entities to implement harmonized data standards and tools.

2.2.3 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. 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. That could involve setting up advisory councils or governance structures that recognize and integrate Indigenous knowledge alongside conventional scientific data. Capacity-building (e.g. in data collection, management and analysis) can further help enable marginalized groups to participate fully in governance and decision-making.

Respecting Indigenous data sovereignty: Governance efforts should prioritize collaborative engagement with Indigenous peoples in developing data that upholds their rights, knowledge systems and self-determined priorities. At the local level, governance frameworks must recognize the inherent sovereignty of Indigenous Peoples over data about them or collected from them, ensuring adherence to the principles of free, prior and informed consent (FPIC).

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. Expanding open-data agreements, supporting decentralized data-sharing platforms and providing funding for NGO data access can help close this gap.

Mainstreaming gender in environmental data strategies: National statistics offices can promote equity by fully implementing Decision 51/115b of the United Nations Statistical Commission (UNSC, 2020), which focuses on mainstreaming gender across all areas of work. In practice, this would mean integrating gender into all areas of environmental statistical production. Decision 51/115 calls on UNSC to convene, review and agree on statistical guidelines to measure gender and the environment.

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. By investing in public data literacy programmes, for example, governments can make environmental information more accessible and understandable to communities. Ensuring that environmental data is communicated effectively can empower citizens to engage in evidence-based decision-making and advocacy efforts.

Diversifying environmental research frameworks and forums: Encouraging the integration of non-traditional research sources and locally generated data into global environmental assessments can help balance the dominance of developed regions'. Similarly, there is 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. Transparency can be strengthened by promoting open-source AI models,

conducting third-party audits and implementing data lineage tracking to make AI-driven decisions explainable and verifiable. Training AI models on diverse datasets, incorporating Indigenous knowledge and developing country perspectives, can limit bias and ensure that environmental decision-making reflects a broad range of experiences and ecological realities. Developing international AI ethics frameworks can likewise prevent data exploitation and misuse, while also ensuring that AI tools are accessible to all, preventing further disadvantaging marginalized communities. Standardized ethical guidelines would provide a basis for regulating AI applications in environmental monitoring and policy development.

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

Potential UNEP actions following from GEDS

Developing and applying ethical principles

- Develop ethical principles for inclusive environmental data governance, for example addressing the imbalance of data from developed and developing regions in global assessment processes and decision-making.
- Work with MEAs and entities such as IPCC and IPBES to embed equity and inclusivity principles into environmental assessments.
- Facilitate the development of AI ethics frameworks to help guide the use of AI tools and prevent data exploitation and misuse.

Building capacity of marginalized groups

- Develop training programmes and digital tools to help marginalized groups collect and manage environmental data effectively and contribute to international assessment processes.
- Establish partnerships with universities, research institutes and NGOs to create mentorship and training networks for data governance professionals in developing regions.

Helping NGOs to empower stakeholders from developing regions

- Develop WESR and other UNEP platforms to ensure that NGOs and stakeholders from developing regions and marginalized groups can access and analyse key datasets.
- Facilitate multi-stakeholder dialogues where NGOs, Indigenous groups and researchers from developing regions contribute directly to data governance policies and frameworks.

2.2.4 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 models and datasets can help streamline data collection and optimize resource allocation by focusing efforts on a core set of essential environmental indicators. This approach reduces the burden on governments and stakeholders while ensuring that critical environmental variables are consistently monitored and updated globally. However, 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. As elaborated in the forthcoming U4E Sustainable Procurement Guidelines for Data Centres and Computer Servers (UNEP, 2025a), national policies can promote the development of energy-efficient, low-carbon data storage solutions, including using renewable energy in environmental data centers. Developing federated environmental data systems and promoting improved interoperability can further reduce duplication of data and the need for costly data processing. As set out in Pillar III, interoperability measures include, for example, actions to harmonize data standards, create modular data systems and catalogue metadata to facilitate discovery and reduce redundant data collection.

Potential UNEP actions following from GEDS

Streamlining environmental data and indicators

- Work with scientific bodies (e.g., IPCC, NOAA, SRC) to identify a set of high-value environmental models and datasets, ensuring scientific rigour and usability. Potentially offer a UNEP certification of 'approved' data sources to encourage the use of trusted, high-quality datasets for reporting.
- Identify a "core set" of priority indicators that align with international reporting obligations (e.g. SDGs and MEAs) and maximize impact, usability and cross-sector relevance. By engaging relevant stakeholders, the process could seek to balance global standards with local adaptability, while learning from the successes and challenges of past initiatives.
- Facilitate better coordination of reporting obligations under the SDGs, MEAs and global frameworks to harmonize and streamline data reporting.

Promoting sustainable and interoperable data infrastructure

- Establish WESR as a federated data system where countries and institutions maintain control over their data but key datasets remain accessible via open APIs.
- Promote national policies on green data infrastructure, supporting low-carbon, energy-efficient data storage solutions powered by renewable energy.

2.2.5 Integrating businesses and finance into environmental data governance

Challenges

Lack of business-oriented environmental data strategies: National environmental data strategies often prioritize government needs, while overlooking the data needs of businesses. Companies require localized, real-time data for risk assessment, sustainability reporting and regulatory compliance, yet current frameworks often fail to provide this. National statistical offices may lack the mandate and capacity to respond to the specific needs of businesses. Earth observation and environmental monitoring data, combined with relevant tools and applications, can support private-sector decision-making and create commercial opportunities. The European Space Agency, for example, puts particular emphasis on meeting the needs of businesses with its data products and promoting innovation and commercial opportunities (ESA, 2021).

Uneven standards for assessing environmental impacts of businesses: The absence of clear, globally accepted frameworks for corporate non-financial disclosures undermines comparability, transparency and effective regulation. Emerging policies like the EU's Corporate Sustainability Reporting Directive (EU, 2022) and initiatives such as the International Sustainability Standards Board (IFRS, 2025a) aim to improve standardization but more efforts are needed to ensure harmonized reporting across sectors. Meanwhile, some industries, including digital technologies and cryptocurrency mining, simply lack standardized models for measuring environmental impact.

Misalignment of MEAs and disclosure frameworks for non-state actors: Governments implement MEAs while businesses often drive environmental impacts. Yet there is little alignment between MEA reporting obligations and private-sector disclosure frameworks and ESG (environmental, social and governance) metrics. This misalignment makes it difficult to integrate corporate and regulatory environmental data, weakening accountability and impact assessments. Stronger coordination is needed to hold businesses accountable while ensuring that regulatory and corporate reporting systems are interoperable.

Responses

Effectively integrating businesses and the financial sector needs into global environmental data governance requires standardization, transparency and institutional coordination.

Addressing the environmental data needs of businesses: Governments and international organizations can improve access to Earth observation and environmental monitoring data for businesses to support sustainability efforts, risk assessments and innovation. They can also develop business-friendly tools that facilitate corporate environmental reporting. For example, the Dutch CO_2 Emission Factors Database provides standardized emissions data to ensure consistency in corporate greenhouse gas calculations.

Harmonizing ESG reporting standards: Harmonization of corporate reporting requirements is being taken forwards by initiatives such as the International Financial Reporting Standards Foundation's collaborative actions to improve standardization of sustainability-related financial disclosures. It could be advanced further by defining sector-specific baselines, similar to the Codex Planetarius approach for agriculture and food, thereby establishing globally recognized benchmarks for environmental disclosures. Developing standardized environmental impact measurement frameworks for emerging industries such as cryptocurrency mining and artificial intelligence, is also important to ensure that corporate ESG data reflect direct and indirect environmental impacts.

Enhancing transparency in supply chains: Strengthening transparency in corporate environmental claims and carbon markets requires robust regulations, 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 being developed via the UN Transparency Protocol, provide an essential complement to disclosure laws by offering a secure means to track carbon footprints, material use and environmental pressures 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.

Potential UNEP actions following from GEDS

Convening and advocacy

- Promote international harmonization of corporate environmental reporting, working with organizations such as the International Sustainability Standards Board and the Organisation for Economic Co-operation and Development.
- Advocate for Digital Product Information Systems and real-time environmental data integration into supply chains, supporting ongoing initiatives by UNTP and the EU.

Capacity-building and technical support

- Assist developing countries in establishing legally binding corporate sustainability reporting requirements, providing technical support to strengthen regulatory frameworks.
- Develop open-access tools for businesses, allowing companies, especially SMEs, to integrate environmental data into risk assessments and sustainability reporting.

Creating business-oriented platforms

- Work with financial institutions to develop decentralized, open-access platforms where ESG and sustainability-related financial data can be accessed and analyzed.

2.3 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.	2.3.1 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	2.3.1 Guaranteeing data sovereignty and security
Domain specific and regional initiatives such as GBIF, ODIS, Eionet and SPREP provide foundations global data governance.	2.3.2 Coordinating global environmental data governance
The Minamata, Basel and Stockholm Conventions have introduced online reporting systems and UNEP's DaRT reporting tool supports reporting to biodiversity conventions	2.3.2 Coordinating global environmental data governance
NILU oversees data management for key international programmes, including the UNECE LRTAP Convention	2.3.2 Coordinating global environmental data governance
U4E Sustainable Procurement Guidelines for Data Centres and Computer Servers	2.3.4 Data stewardship and managing data overload

The Dutch CO_2 Emission Factors Database provides standardized emissions data to ensure consistent corporate GHG calculations	2.3.5 Integrating businesses into data governance
WWF Codex Planetarius is developing minimum environmental performance standards for internationally traded food, offering a model for other sectors.	2.3.5 Integrating businesses into data governance
Product Information Systems such as UN Transparency Protocol offering an essential secure means to track carbon footprints, material use and environmental pressures across value chains,	2.3.5 Integrating businesses into data governance

3 Pillar II: Data quality and provenance

3.1 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. This includes the 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; and 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.

A 10-year vision for data quality and provenance

In 2035, the global environmental data ecosystem delivers accurate, consistent and reliable data, based on robust infrastructures, transparent practices, robust 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, this ecosystem fosters confidence in environmental datasets, enabling informed, equitable and sustainable actions worldwide.

3.2 Key challenges and potential responses

3.2.1 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.

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.

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. The lack of local environmental data hinders effective city and community-level environmental planning and is also an important resource for training AI models.

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.

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. 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. Regular profiling involves analysing datasets to detect missing values, anomalies and format inconsistencies, ensuring that they adhere to established QA/QC protocols. Periodic audits, conducted by independent 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. Adopting structured bias detection methods, like those used by UNODC, can further help identify and adjust for distortions in global assessments.

Leveraging AI to enhance data quality, accuracy and integration: AI has the potential to revolutionize environmental data governance by automating quality control (QC), automating anomaly detection, real-time error identification and predictive modeling. For example, machine learning algorithms can identify 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. AI-powered tools can improve data fusion by harmonizing multi-source environmental datasets from satellites, ground-based monitors and IoT sensors. And AI-powered text analysis can also expand environmental literature reviews, ensuring that scientific contributions from a broader array of language sources are recognized in global environmental modelling and forecasting.

Box 3 Estonia's use of AI to enhance environmental monitoring and reduce human error

Estonia has move 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).

Increasing access to Earth observation data: Expanding Earth observation coverage and international data-sharing collaborations can significantly improve monitoring of underrepresented regions. 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. Expanding participation from governments and private actors can help ensure that decision-makers, researchers and local communities have needed data for climate monitoring, biodiversity assessments and disaster response.

Improving dataset reliability and precision through triangulation and data fusion: Triangulation methods combine independent datasets to improve accuracy and resolution. Combining satellite observations with real-world 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 a decentralized authentication system, where data exchanges triangulate environmental data from different sources, would have substantial benefits.

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. To unleash the full potential of citizen science, there is a need for improved quality assurance mechanisms to enhance reliability and trust in citizen-generated data. Platforms like GBIF and iNaturalist already validate user-submitted biodiversity data. Expanding these QA/QC mechanisms across other environmental domains (e.g., air pollution, waste management and deforestation) would enhance credibility. Developing data translation frameworks and standardizing community-driven datasets can enhance their usability in national and global environmental data systems. In addition, AI-powered validation systems can cross-check observations against authoritative datasets, providing confidence scoring and filtering out unreliable data. There are potentially also opportunities to unlock new local data sources for environmental monitoring. For example, mobile phone tower readings for weather data could potentially be integrated into global environmental monitoring efforts.

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.

Potential UNEP actions following from GEDS

Developing guidance and frameworks

- Develop guidance on the use of AI to improve data quality, including in relation to citizen-generated data.
- Establish guidelines for the ethical and transparent use of AI in environmental monitoring to prevent biases and misinformation.
- Develop guidelines on using participatory science (citizen science) in agency decision-making, helping institutions incorporate valuable local knowledge into environmental governance.
- Establish a protocol for using international datasets, citizen science or models when official national data is unavailable, ensuring transparency, comparability and proper contextualization.
- Contribute to the development of quality assurance (QA/QC) frameworks for citizen science data to enhance its credibility for use in policy and scientific analysis.

Reporting

- Establish regular reports on the state of global environmental data to monitor progress on key environmental indicators and highlight gaps in data availability and quality.
- Ensure transparency in global environmental data by evaluating openness, access and timeliness of datasets.

- Collaborate with ODIS and other platforms to include snapshots of global environmental data systems.

Capacity-building

- Support capacity-building initiatives to help countries integrate EO data into national environmental assessments and decision-making.

Advocacy

- Advocate for stronger international collaboration in EO data-sharing initiatives like GEO and expanded participation from governments, private sector actors and research institutions.
- Promote open-data policies and encourage more space agencies and private satellite providers to release high-resolution EO data for public and governmental use.
- Critically assess the limitations of satellite data to ensure effective environmental monitoring strategies, addressing issues such as resolution, data gaps and alignment with local needs.
- Promote the integration of multiple data sources, including ground-based monitoring, EO data and citizen science, to improve dataset accuracy and completeness.

3.2.2 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. 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 best available 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.

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.

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 enhance sensor calibration, data verification, quality thresholds, decentralized validation and public digital infrastructures.

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. Ensuring that calibration settings, error bars and confidence levels are documented in metadata can enable users to assess reliability.

Box 4 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).

Develop tools to integrate real-time systems with historical datasets: Automated data transformation pipelines and AI-driven data fusion techniques can help harmonize data from different monitoring networks, using contrasting time scales and resolutions. This can also help ensure consistency between real-time and historical datasets, enabling integration, trends analysis and accurate predictions.

Establish standardized QA/QC protocols: Robust quality assurance and quality control processes are needed to ensure that datasets are representative and scientifically sound. They should 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.

Establish minimum quality standards and sector-specific adaptations: Ensuring high-quality environmental data requires both mandatory compliance with international best practices and flexibility to accommodate different use cases. 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 8000, ISO 19157, SDMX and OGC geospatial standards. To implement this effectively, minimum compliance thresholds should be established to ensure that all datasets meet fundamental quality, accuracy, metadata and provenance standards. However, recognizing that data requirements vary across regulatory, scientific and public reporting domains, governments or international organizations could develop sector-specific guidelines that adapt the implementation of these standards to fit different use cases. Communities of practice, bringing together practitioners, researchers, policymakers and data managers, could help in defining such guidance.

Invest in public platforms and clearinghouses to standardize and automate quality assurance: Uptake of QA protocols can be 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.

Implementing established data quality frameworks: The FAIR principles and ISO 8000 standards can support each of the responses above by providing structured frameworks for 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. 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.

Box 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.

Potential UNEP actions following from GEDS

Mapping and coordination

- Convening an expert group to map existing standards across environmental domains (e.g., WMO, IMO, GBIF, ODIS, etc.) to identify gaps, overlaps and inconsistencies.
- Establish communities of practice to address domain-specific challenges, including emerging data types like DNA-based biodiversity monitoring or AI generated data.
- Convene a global working group with governments, researchers, private sector and international organizations to coordinate data validation and interoperability for a group of high-value data sets needed by MEAs.

Guidelines for QA/QC and data processing

- Build an overview of the existing manuals, guides best practices and methodologies. for each environmental domain. For example, ODIS (2025) has already compiled manuals, guides and best practices for ocean data in a repository, which could be used as a template.
- Define global guidelines for environmental data collection, cleaning, aggregation and normalization, applicable to governments, private sector and citizen science.
- Support the development of domain-specific quality standards and metadata documentation and foster mutual recognition of standards.
- Establish a QA/QC framework to validate and verify data, ensuring consistency and reliability.

Capacity-building and training

- Develop training programmes and toolkits to standardize data collection and processing, especially in regions with limited expertise.
- Provide technical guidance on metadata documentation, integration techniques and best practices for environmental data management.

3.2.3 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.

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. Adopting

common provenance standards such as Open Provenance Model (OPM), PROV-O and W3C PROV will 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.

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.

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.

Potential UNEP actions following from GEDS

Guidance and tools

- Develop technical guidance on metadata best practices, specifying recommended formats and required machine-readable provenance documentation.
- Develop standardized metadata templates and checklists to support government agencies, research institutions and businesses in ensuring data traceability.
- Promote adoption of common provenance standards such as OPM, PROV-O and W3C PROV across environmental data platforms to ensure consistency in tracking data origins and modifications.
- Convene stakeholders to discuss and agree on guidelines for AI-generated data transparency, ensuring AI models used in environmental monitoring document training datasets, model parameters and transformation methods.

Convening and advocacy

- Facilitate the designation of authoritative repositories for key datasets to limit dataset duplication, inconsistencies and conflicting versions.
- Develop a certification system or accreditation process for repositories that adhere to transparency and provenance best practices.
- Work with national governments and multilateral organizations to integrate provenance tracking into open data policies and regulatory frameworks.
- Advocate for the integration of automated provenance tracking into data collection systems and widespread adoption of globally unique identifiers (DOIs).

3.2.4 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. Meanwhile the absence of shared standards, methodologies and validation processes in areas such as corporate sustainability disclosures and ESG metrics create further uncertainty and scepticism.

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.

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. Incorporate 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 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, 2023a).

Potential UNEP actions following from GEDS

Dataset accreditation and certification systems

- Develop an environmental dataset accreditation framework to certify datasets that meet rigorous quality, provenance and reliability criteria. Draw on the IPCC validation model for climate data.
- Encourage the adoption of certification standards such as CoreTrustSeal for environmental data repositories, ensuring data is curated, maintained and stored with integrity.
- Support regular expert-driven reviews of dataset utility, providing structured evaluations of their effectiveness and readiness for decision-making.

Guidance

- Develop clear protocols and guidance for incorporating traditional knowledge in assessments while maintaining transparency in its use and ensuring that Indigenous communities retain control over their data.

UNEP data and knowledge management

- Engage Indigenous and local experts in UNEP environmental assessments and validation processes to ensure their knowledge is actively applied and valued.
- Integrate user feedback tools into UNEP data platforms to foster greater transparency and trust in data reliability.

3.2.5 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.

ESG metrics lack needed granularity: Businesses and investors increasingly rely on ESG data to assess supply chain sustainability and carbon footprints, and new rule such as the EU Deforestation Regulation are amplifying demand for such traceability solutions. At present, however, many existing ESG metrics are too generalized to drive effective decision-making. Companies often use industry-average data to calculate supply chain emissions, masking variations in environmental impact between suppliers. This prevents businesses from making truly sustainable choices and limits price differentiation based on environmental performance. Additionally, carbon footprint calculations vary across regions, leading to inconsistencies in emissions assessments. Life Cycle Assessment approaches need greater standardization to ensure comparability and reliability in corporate environmental reporting.

Responses

Identifying priority dataflows 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) and 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).

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.

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.

Harmonizing ESG metrics and leveraging Digital Product Information Systems: Consolidating and aligning ESG standards towards domain-specific minimum reporting frameworks is an urgent priority. WWF's Codex Planetarius provides an interesting example of movement towards industry-wide standardization in the food sector. The uptake of Digital Product Information Systems, such as those developed by the United Nations Transparency Protocol, offer a scalable way for companies to track and communicate environmental impacts across the product lifecycle, ensuring traceability and enabling business to demonstrate their compliance with legal obligations, without requiring a single universal standard. The UNEP Life Cycle Initiative also provides a structured framework to help businesses and policymakers assess environmental performance across the full lifecycle of products and services, supporting the development of robust, science-based ESG indicators and sustainability reporting standards (UNEP, 2025b).

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.

Potential UNEP actions following from GEDS

Convening and facilitating agreements

- Facilitate global agreement on a core set of environmental indicators that can make the global environmental data system more coherent, support decision-making effectively and help target investment in data generation. Align with global reporting frameworks (e.g., SDGs, Paris Agreement, Sendai Framework, and other MEAs) and existing regional prioritization initiatives (e.g. UNECE, SPREP).
- Collaborate with research networks and organizations such as CODATA, Research Data Alliance (RDA), GO FAIR, World Data System (WDS) and Global Open Science Cloud (GOSC) to strengthen requirements for open data sharing and standardized metadata in academic publishing.
- Convene and coordinate efforts to develop industry-specific ESG baseline standards, drawing on the approach in WWF's Codex Planetarius and the work of the UNEP Finance Initiative. The aim would be to achieve a meaningful, globally accepted set of reporting frameworks.

Guidelines

- Work with relevant stakeholders to develop standardized workflows to transform global EO data into national datasets, ensuring they align with policy needs and administrative frameworks.

Advocacy

- Promote coordinated regional EO efforts, such as SPREP's approach in the Pacific and ARD frameworks such Digital Earth Africa to ensure that EO-derived insights are accessible and applicable for local decision-makers.

3.2.6 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 analyze 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.

Box 7 Cross government coordination in New Zealand 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.

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.

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. Japan's 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.

Potential UNEP actions

Facilitating knowledge sharing and best practices

- Identify and analyze best practices from countries that have successfully developed integrated knowledge systems (e.g., New Zealand's climate data program, the U.S. Global Change Research Program). Publish case studies showcasing effective cross-sectoral data integration, environmental justice frameworks and interdisciplinary coordination models.
- Host regional workshops and training sessions to support governments in adopting successful integration strategies and developing national-scale coordination mechanisms.

Strengthening UNEP's own knowledge systems for integrated assessments

- Enhance data infrastructure to support UNEP's Global Environment Outlook (GEO) assessments, ensuring that GEO reports draw on interdisciplinary data sources and provide integrated policy-relevant insights.
- Develop a knowledge platform for integrated environmental assessments, allowing countries to share methodologies, datasets and analytical frameworks aligned with science-policy platforms like IPBES and IPCC.

Supporting national and international data integration

- Develop technical guidance on building interconnected data ecosystems, offering step-by-step approaches for linking environmental, social and economic datasets, with a focus on national policymaking needs.
- Provide technical assistance for integrating environmental justice indicators into national monitoring systems, supporting the development of tools to assess disparities in environmental risk exposure across different socio-economic groups.
- Work with governments and international bodies to align environmental and human health datasets, ensuring better integration of climate and pollution data with food security, disease monitoring and disaster resilience frameworks.

3.3 Overview of best practices in Pillar II

Example	Section
Estonia uses AI to enhance environmental monitoring and reduce human error.	3.3.1 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.	3.3.1 Addressing gaps, inaccuracy and biases in environmental datasets
GBIF and iNaturalist validate user-submitted biodiversity data, enhancing reliability and trust in citizen-generated data.	3.3.1 Addressing gaps, inaccuracy and biases in environmental datasets
The International eDNA Standardization Task Force works to standardize data collection methods for DNA analysis.	3.3.2 Strengthening standards on data collection, processing and QA
The UNECE Pollution Release and Transfer Register system automatically assesses reliability of submissions.	3.3.2 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.	3.3.2 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.	3.3.2 Strengthening standards on data collection, processing and QA
International reporting frameworks such as the ETF ensure that climate data are regularly verified, openly available and structured according to clear methodological guidelines.	3.3.4 Preserving confidence and trust in environmental data
UNECE and SPREP priority indicator sets respond to needs for policymaking and environmental assessments.	3.3.5 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.	3.3.5 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.	3.3.6 Responding to the need for integrated data and assessments
The World Bank's Livable Planet Observatory will facilitate global access to cross-sectoral datasets.	3.3.6 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	3.3.6 Responding to the need for integrated data and assessments
Japan's ecosystem assessments synthesize available evidence, leveraging existing platforms	3.3.6 Responding to the need for integrated data and assessments

4 Pillar III: Interoperability

4.1 Scope and vision

The interoperability pillar addresses the tools and approaches needed to combine and integrate the diverse and fragmented datasets – across domains, regions and platforms – that together make up the global environmental data ecosystem. Key measures includes harmonization of standards for data formats, metadata, APIs and cloud platforms; aligning semantic terminologies, definitions and classifications; documentation of data sharing policies; proprietary v. open-source software and platforms; API design; and use of 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.

A 10-year vision for interoperability

In 2035, the global environmental data ecosystem uses standards that are harmonized but adaptable and transparent.

This system enables seamless integration of diverse datasets across platforms, domains and regions, fostering collaboration, innovation and informed decision-making.

It ensures compatibility and connects environmental data with social and economic information for holistic analysis and sustainable action.

4.2 Key challenges and potential responses

4.2.1 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 5.3). 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.

Major asymmetries in data standards for sustainable finance: Sustainable finance initiatives, including carbon markets, ESG reporting and biodiversity credits, rely on environmental data to assess risks and measure impact. At present, however, asymmetries in data standards make it difficult to compare sustainability performance across industries and regions, which can restrict investment and lead to misallocation of resources. For example, in carbon credit markets there is a need for common standards to remove uncertainty about issues such as carbon capture, deforestation rates and soil health.

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.

Adopting internationally recognized data formats: Publishing data in open-source 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 and SpatioTemporal Asset Catalog (STAC) for cataloguing large datasets. 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).

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.

Box 8 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).

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 and GBIF taxonomies for biodiversity. 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 9 Reducing institutional fragmentation across MEAs

InforMEA offers an example of interoperability in action. By automatically gathering data from MEA secretariats, InforMEA provides a centralized platform for accessing environmental legal instruments, decisions and best practices (UNEP, 2024). This model illustrates how standardized data harvesting and integration, based on common metadata standards and controlled vocabularies, can improve knowledge access and coordination across international organizations.

Potential UNEP actions following from GEDS

Convening and facilitating negotiations

- Lead, together with global partners such as WMO, WHO, IPCC, ISC and the World Bank, global efforts to coordinate around a core set of environmental data standards and facilitate interoperability between national and international datasets.
- Leverage UNEP's partnerships (e.g., GEO/GEOSS, GBIF, CEOS) to drive alignment in environmental data practices and promote global cooperation across governments, research institutions and the private sector.
- Establish a global platform or working group to coordinate standardization efforts, enabling stakeholders to align vocabularies, ontologies and metadata frameworks in collaboration with organizations and initiatives like ISO, OGC, W3C, FAO, EnvO and CDIF.
- Engage with relevant standardization bodies, such as ISO, OGC, W3C and national statistical agencies, to develop an interoperable multilingual environmental ontology framework, based on mapping and integration of existing domain-specific tools, such as the AGROVOC controlled vocabulary, GBIF taxonomies and GEMET environmental terminology.
- Advocate for the adoption of widely recognized metadata standards (e.g., ISO 19115 for geospatial data, Dublin Core for general metadata). Convene key actors (e.g., international organizations, standard-setting bodies, national agencies, businesses) to develop minimum metadata standards aligned with FAIR principles.
- Engage regional and national data agencies to pilot and scale standardization efforts, ensuring solutions are adaptable to diverse use cases and resource levels.

Guidance and tools

- Develop guidance, training and technical support tools to assist governments, research institutions and data providers in implementing standardized formats, metadata frameworks and vocabularies in line with the FAIR principles.
- Support the development of semantic mapping tools that link existing vocabularies.
- Support resource-constrained countries in transitioning to interoperable data systems by providing best-practice guidelines on developing affordable and scalable solutions.

Monitoring and reporting

- Monitoring and reporting on global progress to standardize data formats, metadata and vocabularies, as part of a regular report on the state of global environmental data.

Using WESR as a tool for harmonizing standards

- Exploring the possibility of developing WESR as a tiered global data space, which applies a minimum layer of standards to all data to ensure interoperability, metadata and accessibility, and implementing advanced standards for specific use cases (e.g. climate modelling, regulatory reporting, investments, biodiversity assessments).
- Developing WESR as an exchange for data in different formats and standards and then identifying specific contexts where harmonization is needed to achieve shared goals. A tentative approach like this can help build trust as data providers understand the motivation and value of proposed changes.

4.2.2 Promoting workflow interoperability, documentation and linked data

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.

Discoverability tools can further help in identifying and cataloguing existing workflows, helping researchers and policymakers find and apply validated processes. Platforms such as GitHub, WorkflowHub and Zenodo can facilitate collaboration by hosting open workflows and version-controlled documentation. 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.

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.

Box 10 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).

Potential UNEP actions following from GEDS

Developing guidance and tools

- Develop best practice guidelines for publishing full workflow ecosystems, including data inputs, methodologies, processing tools and outputs. Promote open-source workflow management standards such as CWL and WDL.
- Work with partners to create a centralized registry of validated workflows to help users discover, adopt and adapt established methodologies for environmental data processing and analysis.
- Develop technical guidance on version control, persistent identifiers (DOIs) and API update logging to ensure users can track dataset modifications over time.
- Create toolkits and capacity-building materials to support the adoption of linked data principles and semantic web standards (e.g., RDF, SPARQL, OWL) to improve machine readability and dataset integration.

Convening stakeholders and promoting collaboration

- Establish a global working group on workflow interoperability, including experts from international organizations and initiatives, research institutions and national agencies.
- Work with platforms such as GBIF and ODIS to integrate structured workflows, transparent documentation and linked data approaches into existing environmental data governance efforts.

Monitoring and reporting

- Monitor and report on progress in integrating linked data frameworks and structured metadata into environmental data systems, identifying areas for further alignment and investment.

Supporting implementation

- Work with national agencies, regional organizations and multilateral initiatives to implement structured workflows and semantic mapping tools, showcasing scalable approaches.

- Provide targeted support to low-resource regions and institutions to implement metadata and workflow documentation improvements.

4.2.3 Enhancing API infrastructure

Challenges

Application Programming Interfaces (APIs) play a critical role in 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 APIs 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 APIs 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 API limitations requires increased adoption of open APIs, 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.

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.

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. Requiring standardized API documentation using, for example, OpenAPI would help ensure usability for developers, researchers and policymakers.

Integration of APIs into decision-making and action: Increasing the use of APIs in national and regional environmental monitoring frameworks, can help ensure that real-time data is integrated into policy and decision-making processes. Similarly, the private-sector can be engaged by promoting open APIs that allow businesses to contribute and access environmental data for sustainability reporting, ESG assessments and impact evaluations.

Potential UNEP actions following from GEDS

Coordinating and promoting API standardization

- Convene stakeholders to Identify and promote a limited set of open standard API frameworks (including standards, tools, formats and documentation) to help ensure that environmental data providers follow recognized best practices.
- Advocate for the integration of API-based solutions into national and regional environmental monitoring systems to improve real-time environmental assessments and decision-making.

Developing guidance and tools

- Develop UNEP guidance on API implementation, drawing on existing resources (e.g. US Federal Data Strategy). This guidance could include step-by-step technical templates for designing, developing and deploying APIs, particularly for countries with limited technical capacity.
- Support countries in creating APIs for their environmental datasets, by offering technical guidance based on international best practices.
- Support MEA convention secretariats in developing digital reporting platforms for countries, using APIs for data exchange

Enhancing API infrastructure and discoverability

- Create a Global Environmental API Hub, providing a searchable index of APIs from governments, academia, NGOs and businesses to enable broader access and integration.
- Encourage governments to mandate API access to publicly funded environmental data, ensuring greater accessibility and real-time integration with research and decision-making tools.

4.2.4 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 forwards. 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.

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. 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. Again, CDIF's structured yet adaptable format could provide a model for promoting interoperability without enforcing rigid structures.

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. 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.

Potential UNEP actions following from GEDS

Convening and facilitating global deliberations

- Host high-level dialogues and technical working groups bringing together MEA secretariats, governments, industry leaders, research institutions, standard-setting organizations (ISO, OGC, RDA) and donor agencies to develop a shared vision and a roadmap for interoperability, aligned with broader digital governance initiatives, such as open government data frameworks and sustainable finance reporting standards.
- Engage with institutions developing cross-domain data integration frameworks (e.g., CDIF, SDMX for statistical data, schema.org for structured metadata) to ensure that environmental data exchange aligns with broader efforts in governance, economics and social data systems.
- Engage with donor organizations (e.g., World Bank, Global Environmental Facility, Green Climate Fund, philanthropic organizations) to ensure that funding requirements encourage adoption of harmonized interoperability frameworks, reducing fragmentation in global environmental reporting.
- Engage major technology providers (e.g., Microsoft, Google, Carto, Esri, AWS) to encourage adoption of shared interoperability standards in their platforms and services.

Guidance and technical support

- Develop and disseminate best practice guidelines on how governments and organizations can adopt modular, flexible interoperability approaches.
- Provide technical assistance to low-capacity countries to help them transition towards more interoperable data ecosystems through training, capacity-building programmes and targeted technical support.
- Support pilot projects testing linked open data principles and machine-readable metadata standards, helping build scalable, real-world applications for integrated environmental data.

Monitoring, evaluation and global reporting

- Monitor interoperability improvements, identifying areas where progress has been made and where fragmentation persists. Integrate these findings into regular UNEP reports on the state of the global environmental data ecosystem. MEA secretariats could potentially undertake similar exercises for their specific reporting areas.

4.2.5 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 assessments of their reliance on proprietary platforms, tracking how dependencies evolve over time and identifying proactive measures to diversify their data infrastructure.

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. 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.

Box 11 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 important 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.

Potential UNEP actions following from GEDS

UNEP can play a key role in supporting governments, international organizations and research institutions in implementing these responses by leveraging its convening power, technical expertise and policy influence. Possible actions include:

Convening stakeholders and setting global guidelines

- Facilitate global dialogues on vendor lock-in and interoperability, engaging major cloud providers, governments and open-source advocates.
- Encourage agreements among cloud providers to improve cross-platform data sharing and prevent monopolization of environmental data services.

Promoting open-source solutions and interoperability standards

- Support governments in evaluating and adopting open-source alternatives, such as QGIS, Open Data Cube and Apache Superset, by providing training and technical assistance.
- Encourage national environmental agencies to contribute government-developed tools (e.g., emissions modeling software) to open repositories, following Germany's "open code" and Canada's interdepartmental Python-sharing model.
- Working with bodies such as OGC and ISO to expand the adoption of open standards, ensuring geospatial data is available in interoperable formats (e.g., WMS, WFS, STAC, COG).
- Establishing licensing conditions when public environmental data is monetized by a company (e.g. Apple or Google) and used by a propriety user-facing application for influencing consumer behavior.

Assessing and mitigating vendor lock-in risks

- Conducting periodic assessments of reliance on proprietary platforms, identifying vulnerabilities in the global environmental data ecosystem.
- Advocating for long-term sustainability plans for critical cloud-based platforms, ensuring that essential environmental datasets remain accessible even if private providers change their policies.

4.2.6 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 codevelopment of AI data integration tools (Tangi et al., 2023).

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.

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.

Potential UNEP actions following from GEDS

To support governments, research institutions and other stakeholders in addressing the challenges of AI adoption for data interoperability, UNEP can take the following actions:

Convening stakeholders and facilitating collaboration

- Host global and regional dialogues on AI-driven interoperability, bringing together governments, multilateral organizations, research institutions and the private sector to share best practices, identify common challenges and align efforts.
- Establish a working group on AI and interoperability to develop guidance on AI-enhanced metadata, schema alignment and quality assurance.
- Collaborate with standards bodies such as ISO, OGC and RDA to advance AI-driven approaches to metadata management and data integration.
- Convene discussions on AI ethics in environmental data governance, helping to establish principles that address bias, misinformation risks and algorithmic transparency.

Developing guidance and best practices

- Publish UNEP guidelines on AI for interoperability, outlining how AI can automate metadata generation, schema mapping and data quality assurance, while addressing ethical concerns and compliance issues.
- Develop a practical toolkit to help governments assess AI readiness for environmental data management, including self-assessment tools, implementation roadmaps and case studies.

- Create a repository of AI-driven best practices from global and national initiatives, drawing on insights from organizations such as the European Commission and NASA.

Strengthening technical capacity and training

- Develop capacity-building programmes to equip environmental agencies and policymakers with the skills needed to integrate AI into data interoperability frameworks.
- Offer training workshops and online courses on AI applications for metadata management, schema alignment and data integration, targeting public-sector officials, researchers and data managers.
- Support pilot projects that demonstrate AI-driven interoperability solutions in diverse environmental domains, allowing stakeholders to test and refine implementation approaches.

Promoting AI-ready environmental data

- Encourage governments and data providers to adopt machine-readable data formats and structured metadata frameworks, ensuring that environmental datasets are AI-compatible.
- Advocate for minimum metadata requirements that facilitate AI-driven data discovery and integration, aligning with global standards such as FAIR and PROV-O.

4.3 Overview of best practices in Pillar III

Example	Section
Publishing data in widely used open-source formats such as GeoJSON, GeoTIFF, STAC or CSV is essential to enable data integration and cross-domain interoperability.	4.2.1 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.	4.2.1 Harmonizing data formats, standards and semantics
GBIF, OGC and CDIF provide vital frameworks for aligning formats standards within and across domains.	4.2.1 Harmonizing data formats, standards and semantics
Standardized vocabularies and ontologies such as GCMD Keywords, AGROVOC, ECOLEX and GBIF taxonomies are essential for interoperability.	4.2.1 Harmonizing data formats, standards and semantics
UNEP-MAP drives standardization of data and metadata, facilitating cross-border collaboration and informed policy	4.2.1 Harmonizing data formats, standards and semantics
InforMEA improves knowledge access and coordination across organizations by standardizing data harvesting and integration, based on common standards and vocabularies.	4.2.1 Harmonizing data formats, standards and semantics

DataCommons.org combines structured data from diverse sources into a unified knowledge graph and offer a query interface, enabling users to analyse them.	4.2.2 Promoting workflow interoperability, documentation and linked data
NASA's API portal enables environmental data providers to register their APIs for open access.	4.2.3 Enhancing API infrastructure
Canada's interdepartmental Python script-sharing initiative facilitates environmental data processing across government.	4.2.5 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.	4.2.5 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.	4.2.5 Navigating proprietary software & closed data ecosystems

5 Pillar IV: Accessibility and affordability

5.1 Scope and vision

This pillar addresses measures to ensure that all stakeholders can access and afford the environmental data needed to support sustainable development. This includes actions to make data discoverable (e.g. through cataloguing and data formats); open data and cost reduction measures; mechanisms to navigate legitimate concerns about sensitive data and security; options for increasing access to operational data held by the private sector; and 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.

A 10-year vision for access and affordability

In 2035, the global environmental data ecosystem ensures inclusive, equitable and sustainable access to high-quality data and tools, while ensuring respect 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.

5.2 Key challenges and potential responses

5.2.1 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 kept 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.

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. Metadata databases could serve as showcases of available data, enabling users to assess dataset relevance before requesting access, thereby improving efficiency.

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.

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. 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.

Potential UNEP actions following from GEDS

Monitoring and assessing the global environmental data landscape

- Monitoring environmental data sources, formats, structures, locations and access conditions. Documenting best practices from national and regional initiatives such as Germany's combined metadata portal, which consolidates 40–50 sub-national data portals.
- Using the information from the monitoring of environmental data archives and documenting of best practices as inputs to a regular report on the state of global environmental data, drawing on the approach in the annual report of the UN Office for the Coordination of Humanitarian Affairs on the state of humanitarian data (OCHA, 2024).

Promoting and enabling shared approaches

- Bringing together national and regional data providers, international organizations and technical experts to develop a strategy for linking existing environmental data repositories.
- Leverage partnerships with ODIS, OpenAIRE, CODATA and other global data-sharing initiatives to advocate for standardized metadata frameworks like DCAT to improve dataset discoverability.
- Encourage the development of national and regional repositories that consolidate datasets from different agencies and organizations, ensuring long-term maintenance and accessibility.
- Promote harmonized cataloging standards, for example adoption of SpatioTemporal Asset Catalogs (STACs) to describe geospatial information.

Using WESR to catalogue data and metadata

- Position UNEP's World Environment Situation Room (WESR) as a federated hub, ensuring repositories are connected but without centralizing data ownership. One option could be creating a regularly updated metadata catalogue or directory allowing users to find datasets based on key attributes such as keywords, data quality levels, collection methods and provenance.
- Consider recent proposals by Switzerland on the creation of a global metadata platform.

- Developing an index of “Earth APIs” to bridge gaps between existing repositories and catalogues, linking disparate assets and improving the interoperability of environmental data platforms.

5.2.2 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. Academic paywalls also restricted 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.

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 provide 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.

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.

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 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.

Box 12 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.

Potential UNEP actions following from GEDS

Convening stakeholders and building shared approaches

- Convene governments and donors (e.g., World Bank, Global Environmental Facility, Green Climate Fund) to link open-data commitments to funding eligibility, providing financial and technical support to countries that implement open-data frameworks.
- Encourage public-private partnerships where businesses contribute funding, infrastructure, or expertise to maintain and expand open environmental data repositories.

Guidance and training

- Develop and promote standardized definitions for "open data", "open data standards" and "open data ecosystems" to build a shared understanding across stakeholders.
- Develop international guidelines to help governments implement open-data mandates for publicly funded environmental research, satellite programmes and monitoring initiatives.
- Support the development of standardized licensing agreements to secure free or discounted access to privately held environmental datasets for public interest uses such as research or disaster response.
- Provide technical guidance and training to low-income countries on cost-effective storage solutions and data processing solutions, such as low-cost, cloud-based analytical platforms.
- Develop capacity-building programmes for national and regional institutions, focusing on data-sharing best practices, governance models and legal frameworks for environmental data access.

Investment in platforms and infrastructure

- Develop UNEP's World Environment Situation Room (WESR) as a federated data hub, providing open access to UNEP data, as well as a selection of publicly available environmental datasets.
- 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.

5.2.3 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.

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.

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. 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.

Potential UNEP actions following from GEDS

Developing guidance and policy frameworks

- Develop guidelines and best practice examples of approaches for balancing open access with necessary restrictions based on the use case, drawing on existing frameworks, such as the Aarhus Convention. This could include:
- Decision trees to help institutions determine appropriate data licensing models (e.g., Creative Commons, MIT, non-commercial use, restricted-use agreements).

- Classification frameworks that differentiate between open, restricted and confidential datasets, ensuring a clear and standardized approach to data sharing.
    - Guidance on tiered access models, enabling non-sensitive environmental data to be fully public while providing controlled access to sensitive datasets for accredited users.

Convening and facilitating stakeholder engagement

- Facilitate international dialogues on balancing open access and data sensitivity, bringing together governments, research institutions, private sector actors and Indigenous groups to align best practices.
- Convene technical working groups with key stakeholders, including those involved in the Aarhus Convention and environmental monitoring agencies, to promote consistent classification frameworks and licensing approaches across jurisdictions.
- Engage with international standardization bodies (e.g., OGC, ISO, W3C) to establish best practices for handling sensitive environmental data in global data-sharing initiatives.

Supporting technical solutions for secure data sharing

- Promoting federated data ecosystems, allowing countries to retain sovereignty over sensitive datasets while enabling secure cross-border environmental data collaboration.

5.2.4 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

Limited access to private sector 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 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.

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. 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. And is also possible to create positive incentives for voluntary corporate participation in global data-sharing initiatives, such as GBIF and SDG monitoring, by offering public recognition of sustainability efforts or fiscal incentives.

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. For example, the Common European Mobility Data Space (EMDS) provides a model for secure industry-wide data exchange, ensuring data interoperability without central control.

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.

Potential UNEP actions following from GEDS

Guidelines and tools

- Convening working groups to develop sector-specific guidelines on data-sharing, particularly for industries generating high-value environmental data, such as finance, energy, transportation and agriculture.
- Working with policymakers to develop standardized licensing frameworks that ensure publicly funded environmental data remains open while allowing commercial innovation without undue restrictions. This could include revenue-sharing models, where businesses that monetize public data contribute to maintaining open-access repositories, or licensing rules that prevent commercial actors from restricting access to open government datasets.
- Developing guidance on the use of secure, aggregated data-sharing models, using techniques such as data encryption, anonymization and federated analysis to allow businesses to contribute environmental insights without exposing proprietary details.

5.2.5 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.

Box 13 CITES Trade Database

The CITES Trade Database, managed 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.

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. Finally, AI-driven assistants and automated reporting systems can further enhance accessibility by helping users to generate explanations, reports and insights from complex datasets.

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 14 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.

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.

Box 15 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.

Potential UNEP actions following from GEDS

Guidance and best practices for user-centered environmental data platforms

- Developing guidance and best practices examples for designing user-friendly environmental data platforms, emphasizing accessibility, visualization and action-oriented data presentation, as well as user engagement tools. This could build on best practices from e.g. the Copernicus Climate Data Store, NASA's Earth Observing System Data and Information System (EOSDIS) and FAO's EarthMap.
- Facilitate peer learning and knowledge exchange between platform developers, hosting workshops where successful models are shared and adapted to new contexts.
- Develop training programmes and technical assistance for national and regional institutions to improve their ability to create, maintain and enhance user-friendly environmental data platforms.

Developing WESR as a user-centered environmental data platform

- Ensure WESR is built with user-centered design principles, incorporating visualization and analysis tools tailored to both non-expert and specialized users. Integrate policy and action-oriented tools that link environmental data to response measures.
- Incorporate user feedback mechanisms and consultation processes within WESR, enabling users to report outdated data, request missing datasets and suggest usability improvements. Establish a community forum or knowledge-sharing space, where users can exchange best practices and contribute insights on data usability.
- Develop WESR as part of a federated environmental data ecosystem, ensuring interoperability with other global and national platforms and incorporating the catalogue of existing global environmental data platforms into WESR.
- Collaborate with partners (e.g., Copernicus, GBIF, ODIS, OpenAIRE) to align metadata standards and facilitate cross-platform integration.
- Ensure long-term funding mechanisms for WESR's maintenance, including staffing, continuous data updates, bug fixes and user support. Incorporate open-source tools to further increase resilience.

5.3 Overview of best practices in Pillar IV

Example	Section
OCHA's Humanitarian Data Exchange (HDX) compiles humanitarian data, ensuring discoverability and usability.	5.2.1 Ensuring that repositories are findable and accessible
The INFORM project enables uninterrupted data collection from 14 Pacific Island countries, avoiding duplicative portals.	5.2.1 Ensuring that repositories are findable and accessible
The US requires that all federally funded research, including datasets, be made publicly accessible without embargo	5.2.2 Reducing cost barriers to data access
World Bank initiatives offer technical assistance and funding to countries that commit to open data policies.	5.2.2 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.	5.2.2 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.	5.2.2 Reducing cost barriers to data access
The Aarhus Convention defines rules and criteria that ensure transparency and help determine when access restrictions are justified.	5.2.3 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	5.2.3 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.	5.2.3 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.	5.2.3 Balancing access against concerns about strategic and sensitive data
EMDS provides a model for secure industry-wide data exchange in Europe without central control.	5.2.4 Navigating commercial interests and cloud dependency
The CITES Trade Database requires standardized trade data submission, ensuring consistent, machine-readable info, valuable for policy and research.	5.2.5 Creating user-oriented data platforms

The California Open Data Portal uses a backcasting method to align data collection with decision-making needs.	5.2.5 Creating user-oriented data platforms
EarthMap provides a graphical interface, combining environmental, climatic, social and security factors into a user-friendly decision-support tool	5.2.5 Creating user-oriented data platforms
The Copernicus Climate Data Store is built with continuous user-engagement, to identify gaps and user needs.	5.2.5 Creating user-oriented data platforms
D4C reduces platform duplication and enhances collaboration across international organizations, helping create a transparent global carbon market.	5.2.5 Creating user-oriented data platforms

6 Pillar V: Capacity-building

6.1 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; and fostering the exchange of best practices and innovative solutions to enhance data collection, processing and dissemination.

A 10-year vision for capacity-building

In 2035, the global environmental data ecosystem is inclusive, sustainable and action-oriented. It empowers all stakeholders 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, policy making and decisions, transforming environmental data into a powerful tool for global collaboration and sustainable development.

6.2 Key challenges and potential responses

6.2.1 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, and security and data integrity. 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.

Inadequate security: Weak cybersecurity protections leave datasets vulnerable to manipulation, loss or unauthorized access. Many environmental monitoring systems or critical environmental infrastructure lack adequate encryption, multi-factor authentication, or secure backup protocols, making them susceptible to hacking, data breaches or politically motivated tampering. In some cases, environmental data have been deliberately altered or suppressed to conceal pollution levels, deforestation or climate impacts, undermining evidence-based policymaking. Furthermore, the absence of tools such as blockchain-based verification systems and digital signatures means that many environmental datasets lack clear provenance, raising concerns about their authenticity. Without trusted and authoritative data repositories, environmental data can become fragmented, inconsistent, or unreliable, weakening its role in governance and public accountability.

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. Regional data repositories can 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.

Guaranteeing security and data integrity: To ensure data sovereignty and protect environmental data from unauthorized access, manipulation and cyber threats, governments need to enforce robust cybersecurity protocols, including encryption, multi-factor authentication and regular security audits. International regulatory bodies, such as the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) could support in developing clear security standards and data provenance protocols, ensuring reliability and preventing data manipulation. Technology companies and research institutions can further enhance security by adopting verification technologies, such as blockchain-based systems and digital signatures, to safeguard data provenance and improve trust in the accuracy of environmental datasets.

Potential UNEP actions following from GEDS

Mapping and reporting on the state of ICT infrastructure for environmental data

- In partnership with relevant domain-specific and regional organizations, UNEP can regularly map the state of connectivity, sensor coverage and data storage capabilities in different regions, highlighting disparities and potential investment priorities.
- Developing an interactive online dashboard as part of WESR could provide real-time insights into environmental data infrastructure coverage, sensor deployment monitoring capabilities worldwide.

Developing technical guidance and standards

- In partnership with relevant domain-specific organizations, UNEP could develop and disseminate best-practice guidance on cost-effective sensors, IoT-enabled monitoring devices community-based monitoring approaches, helping countries select the best technologies for their contexts.

Convening actors and facilitating partnerships

- UNEP could convene multistakeholder dialogue, involving governments, regional development banks and funding bodies, businesses and research institutions, to co-develop solutions for environmental data infrastructure gaps, with a focus on investment strategies and financing mechanisms.

6.2.2 Ensuring access to data management and processing resources

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.

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. In addition, governments and research institutions could also open analytical tool repositories: global or regional hubs where researchers and policymakers can access free or low-cost analytics software for environmental modeling. They can also further promote uptake of open-source tools by developing training programmes and guidance tools.

Box 16 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.

Potential UNEP actions following from GEDS

Developing guidance

- Working with relevant international and regional organizations (e.g. ITU, ISO) and governments, UNEP could develop best practices and technical guidance on hybrid and decentralized cloud models and cybersecurity policies. Such guidance could help countries transition to scalable, cost-effective and secure environmental data storage solutions.

Supporting and coordinating regional solutions

- UNEP could support regional organizations (e.g. SPREP in the Pacific, AMCEN in Africa) in developing regional hubs offering shared cloud-based storage solutions, federated data lakes and decentralized processing systems to enhance accessibility while reducing costs.

- WESR could potentially serve as a central coordination hub, linking to regional data infrastructures and domain-specific initiatives (e.g. GBIF for biodiversity, ODIS for ocean data), promoting interoperability and global data integration.
- UNEP could support and help coordinate national and regional efforts to develop interoperable, open-source software for environmental analytics, ensuring low-cost, scalable access to critical tools.

Capacity-building and training

- UNEP can create free or low-cost training modules to promote the adoption of scalable cloud-based data solutions and open-source analytical tools, ensuring that policymakers, researchers institutions fully leverage available technologies.

6.2.3 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.

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.

Box 17 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 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.

Potential UNEP actions following from GEDS

Mapping existing tools and resources and making them accessible

- Working with national and regional organizations, UNEP can conduct regular assessments of capacity-building needs, identifying gaps in technical skills, data management expertise AI literacy within different regions and sectors.
- Conduct a global assessment of existing environmental data training resources across different domains (geospatial, climate, biodiversity, pollution, ocean AI applications), identifying duplication and gaps. Many national and regional organizations, including ESA, FAO, GBIF, NASA, ODIS and OGC, offer free, high-quality training resources but they are currently fragmented.
- Create an online platform for countries and organizations to collect and share good practices, facilitating knowledge exchange and peer learning.

Developing training and educational resources

- Work with partner organizations to develop guidance, learning tools and training programmes based on assessments of country needs and gaps in available learning resources. These could address, for example, basic data literacy; collection, cataloguing and maintaining environmental data, including best practices for data architecture; interoperability and standards; data governance frameworks, policies and laws; ethics and fairness; communication of data; and uptake of environmental data in policy and decision-making.
- UNEP could develop a free, multilingual, online learning platform that offers access to courses, guidance materials and toolkits on all aspects of environmental data governance, ensuring

accessibility for learners in low- and middle-income countries. This could serve as a knowledge hub, connecting to the substantial array of training materials available from partners, such as OGC, ODIS and GBIF enabling user-oriented search functions e.g. differentiating technical sophistication.

- Promote uptake and dissemination of the repository, for example by working with regional organizations, national ministries and universities to integrate it into their courses and professional development programmes.

Working with regional partners

- UNEP can support existing and new regional training hubs that provide localized technical assistance, peer-to-peer learning and tailored e-learning platforms for environmental data governance. These hubs would connect governments, universities and international organizations, ensuring regional capacity-building aligns with local needs.
- In working with regional partners, the aim would be to ensure that training programmes are available in multiple languages, adapted to local contexts designed to be inclusive of marginalized groups, Indigenous communities and women in environmental data leadership.

6.2.4 Strengthening institutional capacities and legal frameworks

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, a lack of clear mandates and slow adoption of data standards. In many cases, statistical offices do not have clear data dissemination policies, making updates irregular and uncertain. Data ownership and confidentiality concerns further complicate governance, as sectors such as fisheries and public health may restrict access due to privacy and regulatory constraints. Even advanced digital technologies cannot overcome human behaviour, culture and poor incentives.

Absence of strategic policy frameworks guiding and coordinating institutions: Many countries lack the strategic and legal frameworks 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).

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.

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. Integrating key international principles such as FAIR (Findable, Accessible, Interoperable, Reusable), TRUST (Transparency, Responsibility, User focus, Sustainability, Technology) and CARE (Collective benefit, Authority to control, Responsibility, Ethics) can help ensure that data is managed ethically and efficiently. Aligning environmental data strategies with national and sub-national digital transformation processes, such as "e-government", "open government" and "open science" initiatives, helps ensure that environmental data governance are embedded within broader national digital policies

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. 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. Relevant reference points include the International Open Data Charter (ODC, 2025) and the World Bank's Open Government Data Toolkit (WB, 2025). Environmental data strategies can, for example, require the use of open licenses (e.g. Creative Commons, Open Government License) to ensure that datasets can be freely shared and reused across public and private sectors.

Implementing national strategies through project level planning: To help operationalize national strategies, public and private projects that generate large-scale environmental data can also be required to develop machine-readable data management plans addressing e.g. data collection protocols, quality assurance, storage methods, interoperability and compliance with national and international standards (e.g. FAIR, ISO 19157, SDMX). Ensuring that the plans are machine readable makes it possible to automate compliance checks, ensure metadata completeness and facilitate integration with national and global data infrastructures.

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.

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.

Potential UNEP actions following from GEDS

Developing guidance documents and toolkits

- Create guidance documents that outline the principles of FAIR, TRUST, CARE and "openness" and link to relevant existing resources; offer step-by-step guidelines for developing national environmental data strategies and set out examples of best practices.
- Provide practical guideline or templates for data management plans, interdepartmental coordination mechanisms and IT infrastructure design, making it easier for countries to align their practices with international standards.
- Providing tools and training to streamline and simplify reporting to MEAs.

Convening and facilitating collaboration

- Work with regional organizations (e.g., African Union, ASEAN) to promote the integration of core data governance principles (FAIR, TRUST, CARE, ODC) into national and regional environmental data strategies, ensuring interoperability and ethical data use.

- Promote private and philanthropic support for capacity building and retention programmes, including through advocacy and convening relevant organizations, businesses and universities.

Capacity-building and assistance

- Create structured online and in-person courses on environmental data governance, ensuring that public officials have both the technical and strategic skills to use data effectively.
- Facilitate regional and international networks and host forums where practitioners can share experiences, challenges and solutions related to environmental data governance.
- Provide technical assistance to countries as they develop and roll out national data strategies, including advice on integrating these initiatives with broader digital transformation agendas.

Designing UNEP knowledge and tools

- Develop WESR with a clear focus on providing actionable insights for policymakers, for example integrating tools addressing policy tracking, impacts of environmental trends and policy responses, and early warning systems.

6.2.5 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. 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.

Potential UNEP actions following from GEDS

Convening and facilitating financial partnerships

- Establish a global forum on sustainable financing for environmental data, bringing together governments, financial institutions, private sector actors and philanthropic organizations to develop long-term financing models for environmental data governance.

Developing policy guidance

- Create guidance and tools to help countries design investment plans and apply for funding from relevant initiatives and development banks (e.g., African Development Bank, GEF, Green Climate Fund, World Bank) to secure long-term financing for environmental data systems.
- Develop best practices and guidelines to help governments integrate environmental data governance into national budgets and generate reviews to finance environmental data systems. This could include guidance on tools such as environmental data service subscriptions, green bonds and climate finance mechanism.
- Create case studies and policy briefs demonstrating how environmental data benefits sectors such as agriculture, disaster preparedness and public health, helping governments justify sustained budget allocations.

6.3 Overview of best practices in Pillar V

Example	Section
SPREP's regional data repository enhances accessibility and reduces storage costs in the Pacific region.	6.2.1 Developing foundational ICT infrastructure
EOSC and OpenAIRE facilitate the sharing and reuse of analytical tools across multiple institutions.	6.2.2 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	6.2.2 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.	6.2.2 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.	6.2.3 Building needed skills and knowledge
SPREP regional knowledge hubs provide training, technical assistance, and tailored e-learning platforms.	6.2.3 Building needed skills and knowledge
IPBES helps users recreate data processes and track provenance through its data management report and capacity-building programmes	6.2.3 Building needed skills and knowledge
World Bank’s Digital Earth Partnership bridges data supply and demand, connecting tech firms with policymakers.	6.2.3 Building needed skills and knowledge
ODC and WB’s Open Government Data Toolkit promote open data as a guiding principle for environmental strategies.	6.2.4 Strengthening institutional capacities and legal frameworks
France’s coordinating body in the PM’s office drives forward environmental data governance across government.	6.2.4 Strengthening institutional capacities and legal frameworks
ESA Fellowships provide structured career pathways for young professionals in Earth observation and remote sensing.	6.2.4 Strengthening institutional capacities and legal frameworks
EU/Finnfund Africa Connected Programme: a public-private partnership focused on improving ICT infrastructure and reducing cost barriers in developing regions.	6.2.5 Securing sustainable funding for data governance

7 Synthesis of potential UNEP actions

The failings of the global environmental data ecosystem are, in large part, failures of coordination and misaligned incentives. Fragmentation in data formats, standards protocols technologies has led to inconsistencies that hinder data exchange. Barriers, both technical, legal and political, prevent effective sharing of environmental data across stakeholders, governments and borders, limiting the potential for collaborative action. A lack of mechanisms to disseminate existing knowledge, tools and best practices in data governance exacerbates the digital divide, leaving many actors without access to solutions that already exist. This inefficiency results in wasted resources and missed opportunities to extract value from data, forcing organizations, especially in developing regions, to reinvent solutions.

Even with better coordination, however, deep imbalances in capacities and resources remain a fundamental challenge. Many governments and institutions, particularly in the low-income countries, lack the physical infrastructure, technical expertise and institutional frameworks to fully participate in, contribute to and benefit from federated environmental data systems. Meanwhile, weak protections for the rights and interests of indigenous groups and marginalized communities raise human rights concerns that demand a fair and inclusive response.

UNEP's position in global environmental governance gives it an important role in addressing these systemic challenges. By assessing gaps, convening stakeholders, facilitating agreements, developing capacity-building tools and helping governments and international partners to target their investments effectively, UNEP can help create a more coherent and inclusive environmental data ecosystem.

The detailed discussion of challenges and responses in Pillars I-V points towards five clusters of potential UNEP actions that follow from GEDS. These address:

i. sustained monitoring and analysis of the global environmental data ecosystem;

ii. convening actors to help move towards shared standards, protocols and frameworks;

iii. advocating for and facilitating the uptake of solutions;

iv. creating a tiered capacity-building framework, geared to stakeholder needs;

v. integrating GEDS priorities into the design and delivery of WESR and other UNEP knowledge platforms and products.

The rest of this chapter briefly illustrates potential actions in each of these areas. The final section identifies a set of priority actions for consideration by Member States.

7.1 Monitoring and analysing the global environmental data ecosystem

All actions to increase coordination in the global data governance and target investments in building capacities require a detailed understanding of what the system looks like today and how it is changing over time. Chapters 2-6 point to the need to build on the analysis undertaken in developing GEDS with a sustained process of monitoring and analysis, addressing key dimensions of the environmental data ecosystem, including:

- **Data availability, quality and interoperability**, e.g. assessing gaps and progress in availability of EO data and progress towards environmental monitoring framework; mapping data archives to make sense of data sources, formats, structures, locations and access conditions; monitoring implementation of QA/QC protocols; and creating snapshots of data systems in different domains.
- **Overlaps and inconsistencies in international data reporting requirements,** identifying opportunities for standardization and alignment across all MEAs.
- **ICT and data infrastructures**, e.g. assessing the state and trends of connectivity, sensor coverage and data storage and processing capabilities in different regions, Earth APIs, highlighting disparities and potential investment priorities; mapping adoption of open-source and cloud-based storage and analytics tools in countries and organizations, and reliance on proprietary platforms; and identifying lessons from existing federated data systems, integrated environmental data portals and national and regional metadata catalogues and repositories.
- **Capacity-building needs and resources**: e.g. assessing capacity-building needs, gaps in technical skills, data management expertise AI literacy within different regions and sectors; mapping and evaluating existing environmental data training resources across different domains (geospatial, climate, biodiversity, pollution, ocean AI applications), identifying duplication and gaps.

7.2 Convening actors to agree shared frameworks, standards and policies

Addressing the problems with the global environmental data ecosystem is partly about aligning different aspects of data governance, including priority data flow, standards and protocols, reporting processes and policy frameworks. There are already important efforts under way in specific environmental domains and regions but much more is needed to link these efforts and fill gaps.

Achieving alignment by imposing global rules from the top would be neither fair nor practically feasible. In many instances, stakeholders lack the resources, capacities and incentives to shift their practices. Instead, change needs to be taken forwards through inclusive global or regional processes (dialogues, working groups and communities of practice), ensuring inclusive representation from low-income countries, Indigenous communities and marginalized groups. The starting point for such processes must be an effort to understand local realities and needs, as a basis for working towards shared approaches.

There may sometimes be instances where it makes sense for countries to agree a recommended or required global standard or approach. To be successful, however, such decisions need to be based on full consultation and restricted to situations where they clearly add value.

Priority areas where global deliberations and alignment are needed include:

- **Data formats and standards**, e.g. convening relevant actors across domains and organizations to align standards and protocols addressing data, metadata, provenance tracking, quality assurance and APIs, including in the context of international reporting obligations; coordinating harmonization of ESG standards; developing an accreditation framework for environmental datasets.
- **Interoperability**, e.g. fostering collaboration among governments, tech firms and research institutions to agree shared interoperability protocols; engaging national and regional stakeholders to

develop a strategy for linking existing data repositories; facilitating dialogues on AI-driven interoperability; developing open cloud interoperability standards for geospatial and environmental data.

- **Priority data**, e.g. working with governments, scientific bodies, global reporting frameworks and international organizations to identify priority environmental indicators while ensuring local adaptability; identify high-value environmental datasets and models and potentially certify their scientific rigour and usability.
- **Data policies and governance**, e.g. convening governments to develop data sharing frameworks that balance sovereignty and security with global environmental needs; strengthening multilateral agreements on data ownership, cross-border access, legal protections, licensing agreements and classification of restricted or sensitive data; agreeing global ethical principles, frameworks and guidelines for inclusive environmental data governance, focusing on AI ethics, bias mitigation, Indigenous data sovereignty and inclusion of participatory science in global assessments.
- **Reporting processes**, e.g. streamlining and harmonizing environmental reporting across MEAs, SDGs and other frameworks; embedding equity and inclusivity in reporting standards; improving coordination with organizations addressing non-environmental data.
- **Financing needed investments**, e.g. convening global forums and dialogues including governments, development banks, philanthropic donors and financial institutions to develop financing models to ensure sustained investment in ICT and data infrastructures and other capacities.

7.3 Facilitating the uptake and implementation of solutions

Implementing effective environmental data solutions requires that UNEP and other international organizations advocate and incentivize their uptake, as well as providing technical support. UNEP can contribute in a broad range of areas, including:

- **Assisting governments in developing environmental data governance frameworks**, e.g. working with governments and regional organizations to develop environmental data governance strategies and frameworks that integrate essential components such as the FAIR, CARE, TRUST and openness principles, and measures to ensure green ICT and data infrastructure; assisting countries in developing corporate sustainability reporting requirements and regulatory frameworks; and promoting use of provenance tracking and Digital Product Information Systems to strengthen transparency.
- **Supporting sustainable, secure data storage and access**, e.g. advocating for recognition of environmental data as a global public good; supporting the development of federated data-sharing frameworks that maintain national sovereignty; providing technical assistance to regional organizations in developing regions to develop regional hubs offering shared cloud-based storage solutions, federated data lakes and decentralized processing systems; working with partners to designate authoritative data sources; and developing sustainability plans for cloud-based platforms.

- **Enabling uptake of harmonized standards and open data policies**, e.g. providing governments technical support to adopt harmonized data, metadata and cataloguing standards, open-source tools, machine-readable formats, dataset certification, structured workflows and semantic mapping tools; engaging with research networks to advance open data and metadata standardization in academic publishing; engaging with donor organizations to link project funding-eligibility to adopting standardized data and interoperability frameworks and open-data commitments, as well as ensuring necessary technical support.
- **Creating a data hub coordinating regional and national initiatives**, e.g. helping governments and organizations to access environmental data by linking regional and domain-specific data stores via WESR; limiting duplication of effort by coordinating national and organizational efforts to develop interoperable, open-source software tools and making them easily accessible in a central hub; including indexing of APIs from governments, academia, NGOs and businesses in this hub;
- **Mobilizing sustainable financing for environmental data**, e.g. fostering private and philanthropic support for long-term capacity-building programmes, for example by convening regional and global forums on financing models; and facilitating public-private partnerships to expand and maintain open environmental data repositories.

7.4 Implementing a tiered framework for building knowledge and skills

Pillars I-V of GEDS set out a long list capability development needs across all areas of data lifecycle, from acquiring basic know-how on environmental monitoring technologies through to sophisticated systems aimed at transforming data into forms that can inspire and shape policymaking and action. Countries and organizations across the world also need training, guidance and tools geared to their specific and highly differentiated needs. To achieve this UNEP could develop a tiered framework for developing knowledge and skills, based on a clear understanding of the capacities of countries and other stakeholders. To illustrate this idea in very simple terms, it is possible to think in terms of three levels of capacity:

- **Foundational level** actors, with limited data infrastructure, governance, or technical skills, and requiring training on basic data literacy, plus data collection and management processes.
- **Intermediate level** actors with some capacity but needing to improve interoperability, governance, and cross-sector collaboration.
- **Advanced level** actors with strong capacities, capable of leading regional or global initiatives and driving innovation.

A first step would be developing a capacity assessment tool (or using or adapting existing tools) to determine where governments and institutions fit on the tiered scale and pinpoint capability development needs. In developing and implementing the framework, initial efforts should focus on the foundational level where needs are greatest.

Pillars I-V of GEDS point to four categories of actions that UNEP could take to build global data governance capabilities: developing **courses and training**, either delivered by UNEP or by others; supporting the development and impact of **regional hubs and peer learning networks** that provide learning

opportunities and technical assistance in multiple language and adapted to local contexts; developing and providing access to available **guidance documents and best practices** to help countries improve their data governance systems; and developing **standardized templates and tools** that can make it easier for countries to adopt best practices and secure assistance. In some domains and regions there are already substantial resources available, in terms of free courses, networks, guidance documents and other tools. Rather than reinventing them, the goal would be to draw on such resources and ensure that they are accessible. Table 1 below sets out examples of the actions that may be relevant to each tier.

7.5 Integrating GEDS priorities into WESR and other UNEP products

For UNEP, implementing GEDS will depend in part on ensuring that global best practices in data governance are integrated into the design and delivery of its data and knowledge products, in particular the World Environmental Situation Room (WESR). The analysis in Pillars I-V highlights various key priorities:

- **Establishing WESR as a federated hub:** WESR would connect and provide access to the environmental data repositories across the world that underpin WESR services, while ensuring that countries, institutions and Indigenous groups maintain control over their own datasets.
- **Promoting interoperability**: In developing WESR, UNEP would need to collaborate closely with organizations like GBIF, ODIS and OpenAIRE to align metadata standards and enhance cross-platform integration. WESR could further promote interoperability standards by incorporating features like automated provenance tracking and dataset validation mechanisms. It could also include index of APIs to improve data platform interoperability globally.
- **Providing actionable insights**: UNEP needs to provide data and knowledge that can drive decision-making and action. In the context of WESR, that could mean including real-time environmental data supporting early warning systems; tracking the impact of policies and regulation globally; developing data and indicator infrastructures designed to support integrated assessment processes such as GEO.
- **Implementing a user-centered approach**: The impact of WESR and other UNEP tool depends on tailoring visualization and analysis tools to both non-expert and specialized users. User feedback mechanisms, such as community forums and consultation processes, can enable a continuous process of user engagement and adaptive improvements.
- **Ensuring inclusivity and representation**: WESR and other UNEP initiatives need to ensure that all stakeholders have equitable opportunities to access and contribute to environmental datasets and knowledge, including environmental assessments.
- **Securing sustainable financing**: To maintain WESR as a long-term, reliable data resource, UNEP needs to secure sustainable funding mechanisms covering staffing, continuous data updates, bug fixes and user support. Leveraging open-source tools and community-driven maintenance models can help increase resilience while reducing costs.

Table 2 Examples of actions that could be included in a tiered learning framework supporting GEDS

	Foundational tier: building awareness and core skills	**Intermediate:** strengthening technical capacity and governance	**Advanced tier**: driving Innovation and global leadership
Courses and training	**Focus:** Basic data literacy, collection, organization, and governance. Training is practical, low-cost and designed to help organizations get started with structured data management. **Data collection and management**, e.g. data collection basic methods; metadata documentation (how to document data for reuse); cost-effective storage and data processing solutions; priority data and indicators. **Governance and ethics**, e.g. introduction to environmental policies and strategic frameworks; basics of ethical data management (principles for data privacy, security and sovereignty); actions to support marginalized groups. **Interoperability and standards**, e.g. interoperability basics (why data needs to be structured and standardized); data standards basics; tools for MEA focal points and national reporting entities. **Basic analytical and cloud-based solutions**, e.g. training modules on scalable cloud-based data solutions and open-source analytical tools.	**Focus:** Strengthening data management, improving governance, increasing interoperability and expanding technical expertise. **Data collection and management**, e.g. implementing QA/QC frameworks; creating, maintaining and enhancing user-friendly environmental data platforms. **Governance and ethics**, e.g. **environmental data governance** and developing legal, institutional and technical frameworks. **Interoperability and standards**, e.g supporting linked data principles (introducing semantic relationships in data); structured metadata frameworks (enhancing data discoverability); basic semantic web standards (RDF, SPARQL, OWL) for structured environmental knowledge graphs. **Technical skills and advanced analytics**, e.g. introduction to AI in data governance frameworks (how AI can support structured data management) and AI applications for metadata management, schema alignment, and data integration.	**Focus:** Cutting-edge AI applications, federated data-sharing, high-level governance and legal frameworks and regional / global leadership in environmental data systems. **Governance and ethics**, e.g. ethical AI and responsible data use (not reinforcing biases, respecting sovereignty, aligning with human rights). **Interoperability and standards**, e.g. advanced use of semantic web standards for federated and machine-readable environmental data; advanced structured metadata frameworks. **AI and advanced analytics**, e.g. AI applications for metadata management, schema alignment, and data integration; developing next-generation AI-driven data harmonization; scaling AI solutions for environmental monitoring and policy. **Infrastructure and emerging technologies**, e.g. developing and implementing storage and processing solutions at scale, including regional cloud-based architectures; standardized tools for federated data-sharing and cross-border environmental monitoring.

Regional hubs and peer learning	**Focus**: Connecting countries to existing knowledge-sharing platforms and regional networks for learning and exchange. For example by: • Providing guidance and support in engaging with regional data-sharing initiatives. • Working with existing regional networks, such as the Africa Environment Information Network to strengthen their capacity building efforts. • Enabling partnerships with more advanced national or regional actors for bilateral capacity-building programmes. • Supporting network-building between countries with similar challenges (e.g., small island states sharing climate adaptation data strategies).	**Focus**: Strengthening regional peer-learning networks, benefiting from case studies and lessons learned across countries. For example: • Working with regional centers of excellence to promote peer-learning • Facilitating regional data governance dialogues to help countries align approaches, e.g. metadata standards. • Promoting joint data initiatives between governments, academia and NGOs (e.g. shared GIS data portals). • Providing support for regional knowledge platforms and thematic working groups (e.g., air quality, biodiversity, ocean monitoring).	**Focus**: Leading mentorship, regional initiatives and global cooperation, and supporting South-South and North-South knowledge exchanges. • Establishing mentorship programmes where advanced actors guide lower-tier countries. • Developing regional public-private partnerships to advance environmental data innovation • Acting as regional hubs for federated data-sharing systems. • Providing training-of-trainers programmes, equipping experts in lower-tier countries to run their own local training initiatives. • Leading cross-regional collaboration, fostering South-South and North-South partnerships.
Guidance documents	**Focus**: Practical how-to guides providing step-by-step guidance on data collection, management, and open data policies to establish basic systems. For example: **Fundamental data governance principles**, e.g. standardized definitions for "open data" and guidance on basic data stewardship and balancing open access with necessary restrictions. **Basic governance structures**, e.g. guidance of formulating roadmaps, management plans and coordination mechanisms in line with the FAIR, TRUST, CARE, and "openness" principles.	**Focus**: Moving from basic environmental data governance to structured, interoperable systems with regulatory frameworks that align with international standards. For example: **Strengthening data governance**, e.g. guidance on using data encryption, anonymization and federated analysis to allow business participation. **Data infrastructure**, e.g. guidance on API implementation, hybrid and decentralized cloud models, and cybersecurity policies. **Transparency and ethics**, e.g. guidelines on tiered access models for sensitive and non-sensitive datasets, ethical and transparency	**Focus**: High-level policy guidance, AI-powered environmental data systems and advanced analytics frameworks. For example: **Advanced data governance and legal frameworks**, e.g. best practices on data policies to support regulatory alignment. **Use of AI for data quality and interoperability**, e.g. guidance and best practices on automating metadata generation, schema alignment etc. while ensuring ethical and legal standards. **Funding and sustainability strategies**, e.g. guidance on developing national and regional

	Technical foundations, e.g. foundational information and best practices on data cleaning, aggregation, documentation, provenance, etc. **Securing support and financing**, e.g. guidance on integrating environmental data governance into national budgets, designing investment plans and applying for international funding.	guidelines for using AI in environmental monitoring, addressing misuse, misinformation and opaque algorithms. **Accessing support and financing**, e.g. guidance on alternative funding models for environmental data systems such as environmental data service subscriptions and green bonds.	investment strategies for environmental data to ensure long-term financing
Standardized templates and tools	**Focus**: Simple tools requiring minimal technical expertise, aimed at supporting basic data management, coordination and policy alignment. For example: • Protocols for using international datasets, models and citizen science data when national data is unavailable • Policy briefs on how environmental data benefits sectors such as agriculture and health to help governments justify spending on environmental data infrastructure. • Modular reporting templates for MEAs, ensuring simplified, structured data submission across multiple reporting obligations.	**Focus:** Structured tools to simplify and harmonize global efforts to enhance data-sharing, interoperability, etc. For example: • Standardized workflows to transform global EO data into validated national datasets, ensuring alignment with national policy needs and administrative frameworks. • Technical templates for API development in low-resource settings. • Standardized frameworks for classifying datasets as open, restricted or confidential • Decision trees to help institutions determine appropriate data licensing models	**Focus**: Standardized tools to facilitate development and implementation of best practice governance mechanisms. For example: • Standardized licensing frameworks to ensure that publicly funded environmental data remains open while allowing commercial innovation, e.g. revenue-sharing models. • Standardized licensing agreements for securing free or discounted access to privately held environmental datasets for public interest uses.

7.6 Priority actions for Member State consideration

Sections 7.1-7.5 summarize the broad array of potential actions that UNEP could undertake to strengthen global environmental data governance. A selection of actions stand out as key priorities. In some cases these actions would require mandates and financial resources to implement. They are therefore presented here for Member State consideration and possible action at the next session of the UN Environment Assembly.

1. **Promote GEDS principles through the continued development of WESR**. This means establishing WESR as a UNEP data and applications platform for Member States, the UN system and the public to support decision-making and action. WESR should integrate data from a variety of sources, including UNEP projects, third-party data platforms, governments and civil society organizations. In addition, WESR should include tools to analyse and visualize multiple datasets to allow exploration, exposition and storytelling. WESR should implement rigorous data quality standards and ensure a robust data governance framework to maintain the reliability and credibility of the platform and safeguard UNEP's reputation as a trusted and authoritative source of information about the environment.

2. **Promote uptake of GEDS principles at country level through pilot projects**, such as the current UNEP-GIZ project, "Capacity and use case development for environmental data-driven value creation and innovation", which strengthens data partnerships, exchange and national capacities in the East Africa region. By promoting integration of data across scales and creating digital public goods, the project aims to drive innovation and sustainable economic growth, advancing the SDGs.

3. **Create a Global Environmental Data Governance and Classification Framework** to guide countries in developing national environmental data strategies and policies. Building on existing data governance frameworks implemented in some countries, the framework would set out elements such as environmental data governance principles (e.g. on sovereignty, privacy, ethics, security), data classification frameworks, and technical and interoperability standards. Rather than a rigid system, it would serve as a baseline of best practices and recommendations, allowing UNEP to work with Member States individually to customize and implement it within national contexts.

4. **Develop and implement a tiered capacity-building framework** that identifies and responds to the needs of individual countries and organizations. Based on capacity assessments, UNEP would develop courses, guidance documents and adaptable decision-support tools (such as the proposed Global Environmental Data Governance and Classification Framework) that can be used by countries with assistance from UNEP or other UN entities and regional organizations. It would also facilitate the exchange of relevant knowledge and best practices by facilitating the establishment of regional hubs and peer learning networks, and by establishing an online exchange platform to collect and share best practices.

5. **Lead a process to identify a global core set of environmental indicators** to simplify reporting, focus investments in data collection and management, align data across countries and domains, and generate robust inputs to integrated assessments and policymaking. The process would need to promote alignment with SDGs, MEAs and other global frameworks. It would also need to balance

global standardization with national adaptability, drawing from existing initiatives such as the UNECE core set of environmental indicators.

6. **Convene an Expert Group on Interoperability Standards** to work to harmonize data formats, metadata structures, API protocols and semantic classifications to ensure that environmental datasets from different sources can be combined and used for global monitoring, policy and decision-making. The group could include UN entities, national environmental agencies, space agencies, research institutions, industry stakeholders and standard-setting organizations. It would necessarily build on existing initiatives led by, for example, CODATA, GEO, GBIF and WMO.

7. **Establish a global clearinghouse for environmental data quality** to help build trust in environmental data, encourage best practices in data collection and management, and provide governments, researchers and businesses with a clear framework for assessing data reliability. This would necessarily need to take a pragmatic, incremental approach to avoid creating an overload of work. For example, UNEP could convene an expert group to develop a classification system, defining data quality levels and related application areas for the data. Once established, data providers that desired a UNEP-backed "stamp of approval" could voluntarily submit their datasets to the expert groups for evaluation against these standardized criteria.

8. **Explore options for a Global Environmental Data Utility** to provide equitable access to a wide range of environmental data under a shared policy framework. The utility would serve as a centralized access point, ensuring that developing countries can obtain critical datasets for free or at low cost. To sustain this model, a long-term funding mechanism would be required to compensate or subsidize data providers, ensuring continued accessibility and reliability.

9. **Develop a strategic approach to support MEAs in enhancing reporting processes**, enabling more effective contributions to the global environmental data ecosystem. UNEP could work with MEA secretariats and national focal points to identify opportunities for modular reporting systems that enable countries to efficiently use reported data across multiple agreements, integrating shared data standards and interoperability frameworks. It could also engage with key funding bodies such as the GEF and GCF to explore opportunities for assisting countries in transitioning to digitized, standardized reporting systems, making MEA data more actionable while ensuring flexibility for national contexts.

Member States are invited to consider these priority actions and explore other potential avenues for implementing the actions proposed across Pillars I-V.

Strengthening global environmental will require sustained collaboration, investment and innovation. UNEP stands ready to support Member States in achieving the vision of "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".

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Annex UNEP analysis and consultations in developing GEDS since 2021

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.

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.

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.

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?

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