TRAINING MANUAL

Integrating data to improve the protection and restoration of freshwater ecosystems

UN environment programme
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Global Water Partnership 25 YEARS
Cap-Net
UNDP

This project is being jointly implemented by the Global Water Partnership and Cap-Net, with the support of the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP), and under the guidance of UNEP-DHI.

ABOUT GWP

The Global Water Partnership (GWP) vision is for a water secure world. Our mission is to advance governance and management of water resources for sustainable and equitable development.

GWP is a multi-stakeholder action network and intergovernmental organisation dedicated to working with countries towards the equitable, sustainable, and efficient management of water resources. We comprise 3,000+ partner organisations in over 180 countries. Our Network of 65+ Country Water Partnerships and 13 Regional Water Partnerships convenes and brokers coordinated action by government and non-government actors. A long-time advocate for integrated water resources management, we draw on implementation experience at the local level and link it across our Network and to global development agendas.

ABOUT CAP-NET

Cap-Net is UNDP´s global network for capacity development in sustainable water management within the Global Water and Oceans Governance Support Programme. Our work and strategic directions are in eradicating poverty in all its forms and dimensions; accelerating structural transformations for sustainable development; and building resilience to crises and shocks.

Cap-Net's vision is "Water Knowledge for All: Empowering Individuals, Enabling Environments" and its mission is strengthened individual and institutional capacity, and knowledge base to formulate and implement relevant policies, laws and strategies at country, regional, water basin, and source-to-sea scales.

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FOREWORD

Freshwater ecosystems have enormous biological, environmental, social, educational and economic value and provide a range of goods and services upon which people, and all life, depend. Ecosystems purify fresh water, regulate flows, supply water and food to billions of people, drive the water, carbon and nutrient cycles, harbour exceptional freshwater biodiversity, and enable the productive use of water for drinking, agriculture, energy generation, navigation, employment and tourism.

Freshwater ecosystems in the context of the Sustainable Development Goal (SDG) framework are foundational natural resources of the biosphere. Numerous development actions depend on them, and either succeed or fail depending on the functional capacity or integrity of the ecosystem. Any adverse changes in the quantity and quality of freshwater ecosystems ultimately reduce our capacity to develop sustainably.

Globally, observable changes to freshwater ecosystems and hydrological regimes are being caused by human activities. Demand for water and land from the increasing population has redefined the natural landscape into agriculture and urban land. Global precipitation and temperature changes exacerbate the problem. Freshwater ecosystems quantity and quality is currently being compromised. We now know through satellite observations that the extent of surface water available in a fifth of the world's rivers basins has changed significantly during the last 5 years, when compared to the last 20 years. These observable changes represent areas of flooding, through a huge growth in reservoirs and flooded agricultural land, and areas of shrinking surface water, corresponding to the drying up of lakes, wetlands and floodplains, and the loss of many seasonal waterbodies. In addition, more than 80 per cent of the world's wetlands are estimated to have been lost since the pre-industrial era. Yet wetlands are needed to mitigate climate change, reduce the impacts of floods and droughts, and protect freshwater biodiversity loss.

What can be done to change these adverse ecosystem changes? As users of this manual and participants in the training sessions, it is hoped you will gain an understanding of the role and value of freshwater ecosystems within different sectoral contexts and an overview of actions and management solutions to protect them. There are three areas of action that require acceleration. First, we need to increase the uptake of freshwater data into all those sectoral processes that depend on water but may not understand the impact of their socially and economically driven decisions upon the environment. This requires the promotion, sharing and dissemination of readily available freshwater data across sectors, institutions and companies that are heavily dependent on fresh water. Second, we need governments to implement and enforce national and river basin-level policies, laws and practices to provide effective protection of freshwater ecosystem integrity and undertake large-scale restoration of degraded freshwater ecosystems. Third, we need improved coordination across institutions working on fresh water. Given the central role of healthy ecosystems in achieving water security and sustainable development, effective coordination among the institutions working on various aspects of social, economic and environmental water-related objectives and therefore advancing the implementation of Integrated Water Resources Management is a must.

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Welcome to the course

This training manual has been developed as a key component of the pilot project "Integrating freshwater data into sector-wide decision making to improve the protection and restoration of freshwater ecosystems". The pilot project is implemented by GWP and Cap-Net, with the support of the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP), under the guidance of UNEP-DHI.

The training manual is designed to raise awareness and capacity of decision makers, managers and practitioners in protection and restoration of freshwater ecosystems through enhanced understanding of the role, value and importance of protecting and/or restoring freshwater ecosystems, understanding of actions and management solutions, and on the use and application of data.

Course description

Freshwater ecosystems are critical to the achievement of the Sustainable Development Goals (SDGs). They provide crucial ecosystem services, sustain livelihoods and economic development, and support biodiversity. Unfortunately, freshwater ecosystems are facing serious accumulative pressures, affecting their ability to provide these services. These pressures include pollution and overextraction for socioeconomic uses, compounded by the impacts of climate change, land-use change and invasive species. The challenges of sustainable ecosystem management largely revolve around finding the balance between the need for short-term socioeconomic development, which often puts extra pressures on ecosystems, and the need to protect and restore ecosystems to support more long-term, sustainable development. This process puts the emphasis on understanding the situation, the decisions at stake, and then defining a set of actions and corresponding tools for the management of water-related ecosystems.

Application of data to provide the information and evidence for decision-making is increasingly essential for freshwater ecosystem management, protection and restoration. Unfortunately, and despite the increased availability of data especially through the data revolution and technology, uptake of data for decision-making is often limited. Data is only as valuable as the decision it enables – including status and compliance monitoring, planning and action. Understanding how to access and apply available data sets can help to improve decisions for different situations and to communicate more effectively with stakeholders.

Course structure

For the online self-paced course, participants will have 30 days to complete the four modules of the course at their own pace. Total time dedication is approximately 3 to 4 hours per module, for a total of 16 hours for the entire course, or equivalent to two days of full-time study. Country-specific training will differ based on each specific context in terms of delivery; however, participant dedication remains the same.

The course is a foundational programme for participants. It creates understanding on action planning for protection and restoration of freshwater ecosystem, and how data through multi-stakeholder processes can be applied to actionable operational insights.

The manual consists of four modules:

- Module 1: Structure, functions and value of freshwater ecosystems
- Module 2: Protecting and restoring freshwater ecosystems
- Module 3: Data for decision-making
- Module 4: SDG 6.6.1 Explorer platform

Modules 1 and 2 focus on improving the understanding of decision makers and practitioners in the protection and restoration of freshwater ecosystems and provides examples of the processes that can be employed in identification of priority freshwater ecosystems and action plan development. Module 3 examines how data can be used towards improved decision-making with specific reference to data sources and practical tools available for the protection and restoration of freshwater ecosystems. Module 4 then provides guidance on the use and applications of the recently developed SDG 6.6.1 Freshwater Ecosystems Explorer platform, which is the global reference platform for monitoring of SDG target 6.6.

Target

The course has been designed for those who strive to play a role in the protection and restoration of freshwater ecosystems in their respective countries or regions:

- Decision makers, mandated institutions and stakeholders in infrastructure, water, forestry, agriculture, climate change, biodiversity, land use and urban planning, who may influence the frameworks for ecosystem restoration and/or protection in the target countries.
- Individuals working in multilateral and bilateral organizations who support the restoration and/or protection of freshwater ecosystems.
- Individuals working in the private sector, foundations and other non-traditional investors in freshwater ecosystems.

Aim

The overarching objective of the training is to raise awareness and capacity of decision makers, managers and practitioners in protection and restoration of freshwater ecosystems through multi-stakeholder engagement and application of relevant knowledge in decision-making processes.

Learning objectives

In this course, the participants will be introduced to:

- The characteristics, functioning and value of freshwater ecosystems.
- Approaches to protect and restore freshwater ecosystems.
- Techniques and platforms for collection, access, analysis and visualization of freshwater ecosystems data, and their contribution to decision-making at different levels.
- Applying and integrating diverse data sources for management of freshwater ecosystems.

Module 1: Structure, functions and value of freshwater ecosystems

A. Goal

This module aims to improve the understanding of decision makers and practitioners in the protection and restoration of freshwater ecosystems, outlining their role, value and importance, as well as drivers of change.

Learning objectives:

Upon completion of this module, participants should show a good understanding of:

- The characteristics and diversity of the various freshwater ecosystems
- Dynamics of changes in freshwater ecosystems and threats
- Water-related ecosystem services
- Perspectives on ecosystem services valuation
- Contextualization:
    a) Two or three examples of different sectoral contexts and role of freshwater ecosystems for those sectors at the country and watershed level
    b) Quantified example(s) of valuing ecosystem services and business cases for protection of ecosystems (in the country or region)

B. Introduction

The natural environment plays an integral role in achieving the Sustainable Development Goals (SDG). Achieving lasting progress in social and economic domains requires the sustained provision of environmental goods and services, derived from functional and healthy ecosystems. Freshwater ecosystems – including lakes, rivers, wetlands and groundwater – possess enormous biological, social, educational and economic value. They underpin sector-wide activities including water for drinking and sanitation, agriculture, employment, energy generation, industry, navigation, recreation and tourism. They also provide important ecosystem services, such as naturally purifying fresh water, regulating flows, mitigating extreme conditions, acting as carbon sinks, supporting climate adaptation and providing a cultural link between people and nature.

Recognizing the importance of freshwater ecosystems for Agenda 2030, SDG target 6.6 aims specifically "to protect and restore water-related ecosystems". Unfortunately, freshwater ecosystems are increasingly facing serious pressures driven by human activities, including pollution, overextraction, encroachment and flow alteration, and the pressures are further exacerbated by climate change. According to data gathered worldwide in the 2020 UNEP Water Data Drive, one fifth of the world's water basins are experiencing rapid changes in the area of surface waters. Policymakers, together with stakeholders, need to better understand the importance of water-related ecosystems and the threats they are facing, and implement appropriate measures to protect and restore them.

As freshwater ecosystems are complex, dynamic and diverse, it is important to understand their key characteristics, value, dynamics and drivers of change for action. The module will provide the participants with an overview of these different topics.

C. The diversity of freshwater ecosystems and their characteristics

Module 1 will discuss a broad typology of freshwater ecosystems, with their main characteristics. Although this typology is commonly applied, other classification typologies may be used. Often, a finer scale of classification is adopted for the assessment of ecosystem conditions and design of appropriate management responses, for example using an “ecoregion approach”. Ecoregions are areas where the ecosystems have similar characteristics and are generally subdivisions of hydrological drainage basins. Some countries also have adopted specific classification systems, which we recommend taking into account when working on interventions within specified countries.

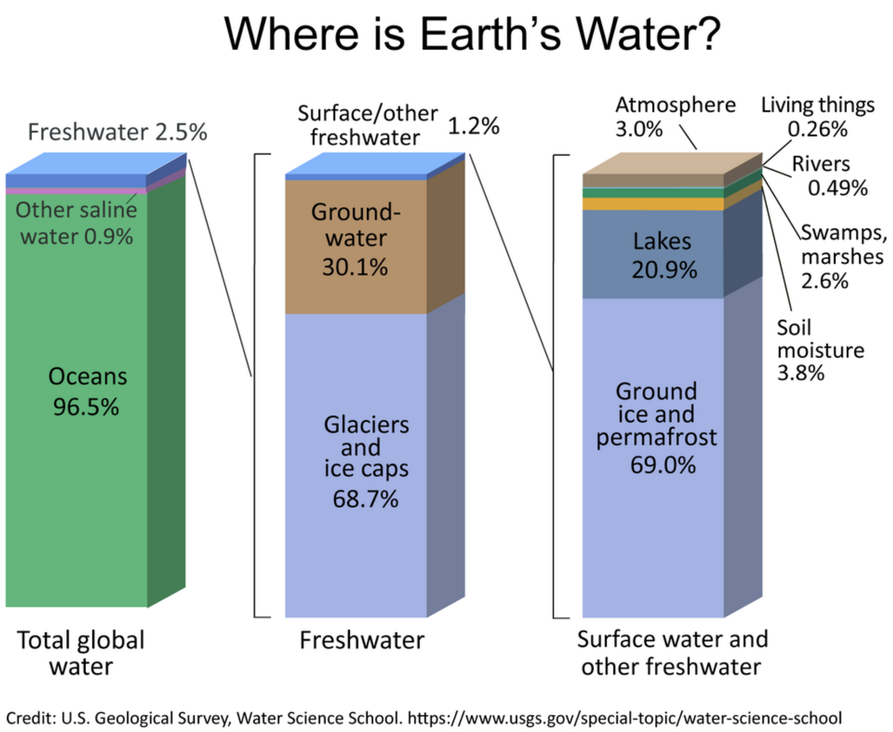

Figure 1.1: Water proportions on Earth.
Credit: US Geological Survey, Water Science School. https://usgs.gov/special-topic/water-science-school.

An ecosystem is a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit (UN Environment, 2017). Aquatic ecosystems are defined as the abiotic (physical and chemical) and biotic components, habitats and ecological processes contained within rivers and their riparian zones, reservoirs, lakes and wetlands and their fringing vegetation. For the purposes of this document "freshwater ecosystems" include all inland surface aquatic ecosystems with salinities of less than 1 per cent. The main distinguishing characteristics of inland surface waters are as follows:

- They are linear or mosaic features embedded into the terrestrial matrix.
- They are typically located at the topographically lowest point in the landscape, thereby collecting and conveying materials (water and dissolved and particulate matter) from within their entire catchment.
- They may expand, contract and fragment, leading to rapid changes in volume and/or area.
- They are closely linked to and mutually dependent on adjacent terrestrial (surface and subsurface) and, in many cases, marine systems.

These unique properties make inland surface fresh waters among the most complex, dynamic and diverse ecosystems globally. This has major ramifications for management. The catchment (or basin) is the key unit for conservation and management. Connectivity within the freshwater ecosystem – longitudinally, laterally and vertically – is fundamental in understanding and managing inland surface waters. Most freshwater ecosystems are disturbance-driven systems shaped by hydrological, morphological and biological events. For example, hydrological connectivity, the water-mediated transfer of energy, matter and organisms among and between the elements of the hydrological cycle, controls biodiversity and ecosystem processes and services on the catchment scale (Bunn and Arthington, 2002).

Inland surface waters contain disproportionately more species per unit area than marine and terrestrial ecosystems. Our current knowledge of freshwater species diversity varies greatly between groups of organisms, and existing diversity is very much underestimated. Even among freshwater fish, almost a hundred new species have recently been described per year in South America alone (Abell et al., 2008).

In general, freshwater ecosystems can be divided into two groups: lentic ecosystems and lotic ecosystems. Lotic ecosystems are those that have running waters, such as rivers and other water currents. They are characterized by having unidirectional flow, or flow of water in a single direction. On the other hand, lentic ecosystems are standing or very slow-moving water, such as lakes, lagoons, ponds, natural pools, swamps, vegetated wetlands and other flooded plains.

It is noteworthy that SDG target 6.6 also identifies aquifers as being part of water-related ecosystems, but this course will focus on surface waters. The data, knowledge and approaches to action for aquifers present unique characteristics that require a separate focus.

1. Lotic ecosystems (rivers and streams)

Lotic systems are mainly characterized by moving freshwater systems. Figure 1.2 highlights the diversity and geographic details of these.

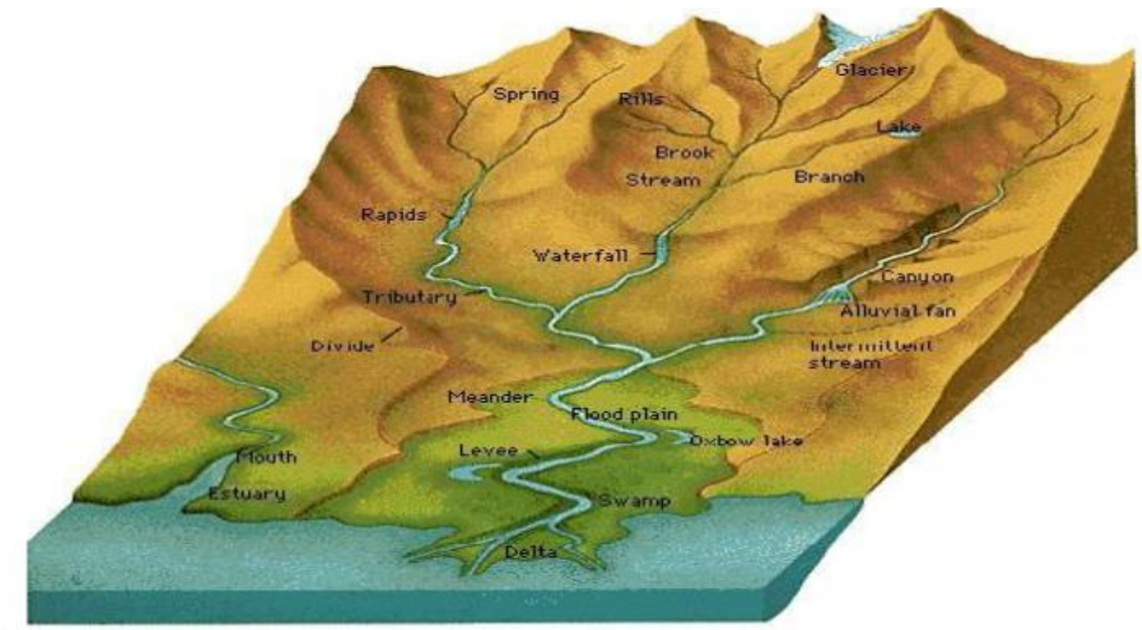

Figure 1.2: Lotic system: drainage basin (or river basin/watershed). Source: www.3dgeography.co.uk/river-diagrams.

Water currents originate in higher altitude areas, such as mountains or upland ranges. They can arise by the action of groundwater that rises to the surface as springs, by the melting of perpetual snow or glaciers or via the catchment of rainwater, among others. The downhill flow leads to bigger rivers, which flow into a lake, the sea or the ocean. These systems are quite diverse, including for example headwater streams, intermittent streams and lowland open floodplain streams (see figure 1.3). Physical and chemical characteristics vary depending on the location of the watercourses, with for example lower temperatures, higher dissolved oxygen and usually lower turbidity at the origin of the river as compared to its mouth. The salinity of the water is also another component that increases from the (nascent) head to the mouth depending on the type of soil that drains the basin.

The flora and fauna of watercourses varies in diversity and morphometrics depending on the river course and section. Fauna such as fish at the headwaters are adapted to resist the high currents by clinging or burrowing. Flora such as the common reed (*Phragmites australis*) present strong physical attachments to substrate by roots, flexible stems and streamlined leaves. In the middle course, fish occupy the waterbody and there are several macrophytes. In lower watercourses, the water typically has a darker hue mainly due to the retention of sediment and enrichment of decomposing litter and dissolved tannins from the surrounding vegetation. Terminal reaches can sometimes have estuarine conditions as they might be close to the river's mouth. Some fish (e.g. eels and salmon) and crustacean species (e.g. *Macrobrachium* sp.) rely on traversing freshwater lotic systems to the brackish and even marine habitats for completion of their life cycle.

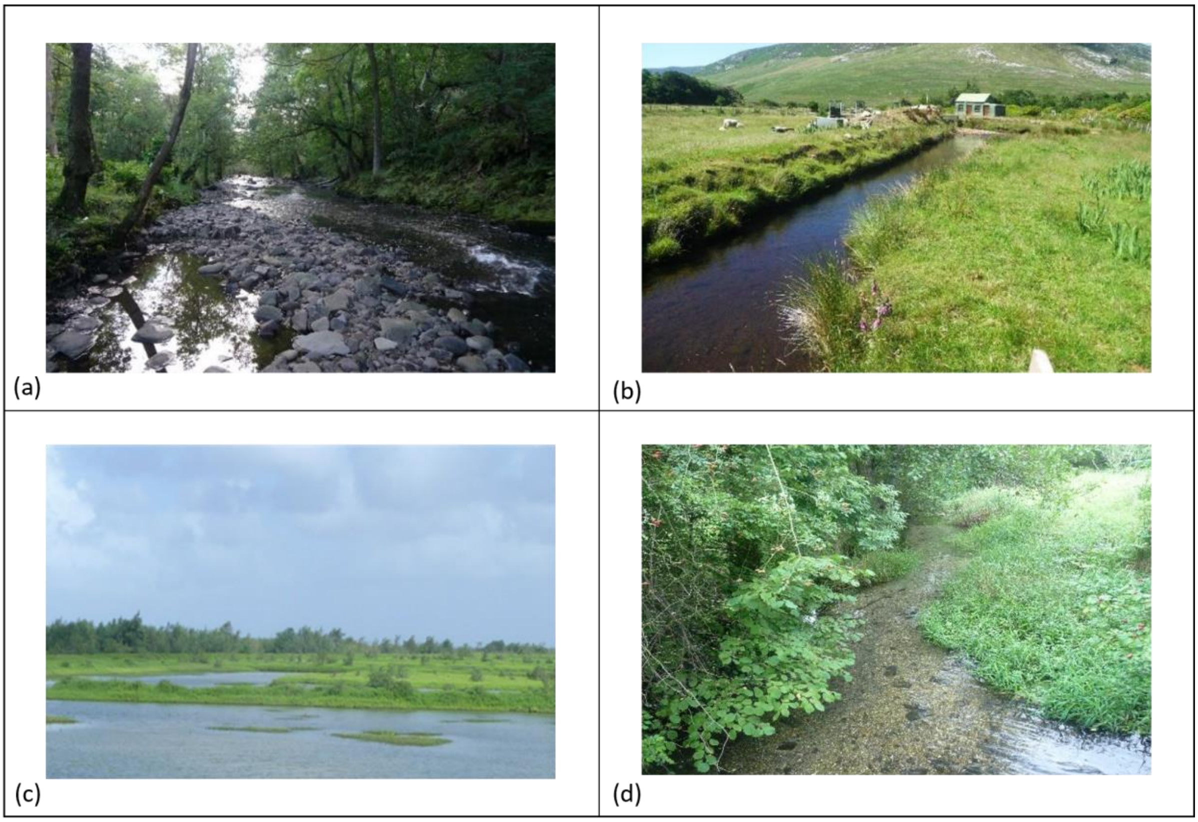

Figure 1.3: Examples of lotic ecosystems (a) headwaters, Cardiff, Wales; (b) Creek, near Loch Furness, Ireland; (c) floodplain stream, Guyana; (d) brook, New Port, England (Photographs, Ryan S. Mohammed).

2. Lentic ecosystems

Lentic systems are standing water systems characterized by water that has a longer residence time (how long water stays in the system) and as a result possess the following features:

- Deposition of suspended particles to the bottom of waterbodies.
- Development of phytoplankton and zooplankton and lacustrine fish communities.
- Presence of complex vertical water cycling instead of a unidirectional current as in running waters.
- Mixing of upper and lower water may be limited due to thermal stratification (separation of water into layers due to differences in density).

Lentic systems with limited anthropogenic impact can be clear water, which allows light to penetrate to benthic and fringing (littoral) communities with macrophytes and other plants. Some might have suspended solids from the associated substrate or have high algal content as a result of eutrophication. Shallow lentic systems are ideal habitats for plants such as submerged rooted pondweeds (*Elodea*) whereas deeper waters such as in Lake Baikal can have large plumes of submerged algae. Lentic systems include wetlands and lakes.

(a) Wetlands

Wetlands are some of the most critical and scarce freshwater ecosystems. Although they cover only roughly 6 per cent of the Earth's land surface and are most common in temperate and boreal regions, wetlands perform a wide range of ecosystem functions, many of consequence on a global scale. Wetlands are ecosystems saturated with water, either seasonally or permanently. They are characterized by hydric soils, in which anaerobic conditions prevail, and support unique habitats.[1] They can be either anthropogenic or naturally occurring.

Their ecosystem services include cycling of nutrients, breakdown of organic matter and filtering of sediments. Carbon sequestration (capturing and storing atmospheric carbon dioxide) is typically thought of as a terrestrial vegetation type ecosystem function; however, recent investigations have shown that wetlands store large concentrations of carbon compounds within their substrate and vegetative tissues.

Plants that grow in wetlands need to have special adaptations which allow them to grow in low-oxygen and acidic conditions. The surface of the water and the wetland bottom provide habitat for multiple life stages of aquatic and terrestrial insects. Fish, amphibians and reptiles depend on the habitat provided by wetlands. Additionally, many bird and mammal species use the water and its adjacent shores. Figures 1.4 and 1.5 highlight various wetland types and structure.

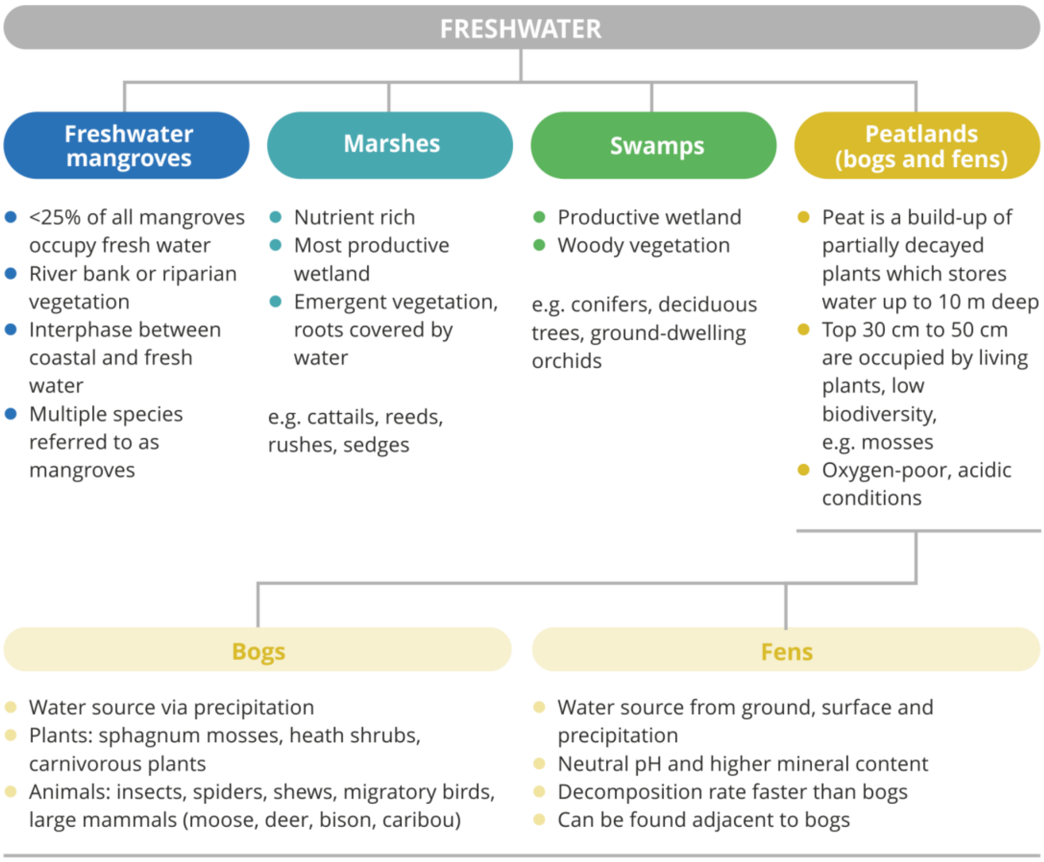

Figure 1.4: Wetland types, structure and biodiversity.

[1] The precise delineation of wetlands at national, subnational or local scale depends on the definition of wetlands applied, as criteria may vary. Vegetated wetlands as defined by SDG 6.6.1 are water-dominated ecosystems such as swamps, swamp forests, marshes, peatlands, paddies and mangroves. Additionally, the estimates of the area occupied by wetlands globally are being updated and improved as studies and methods for identification are dependent on the definition of wetland to be taken, whether or not they include lakes and coastal areas among others.

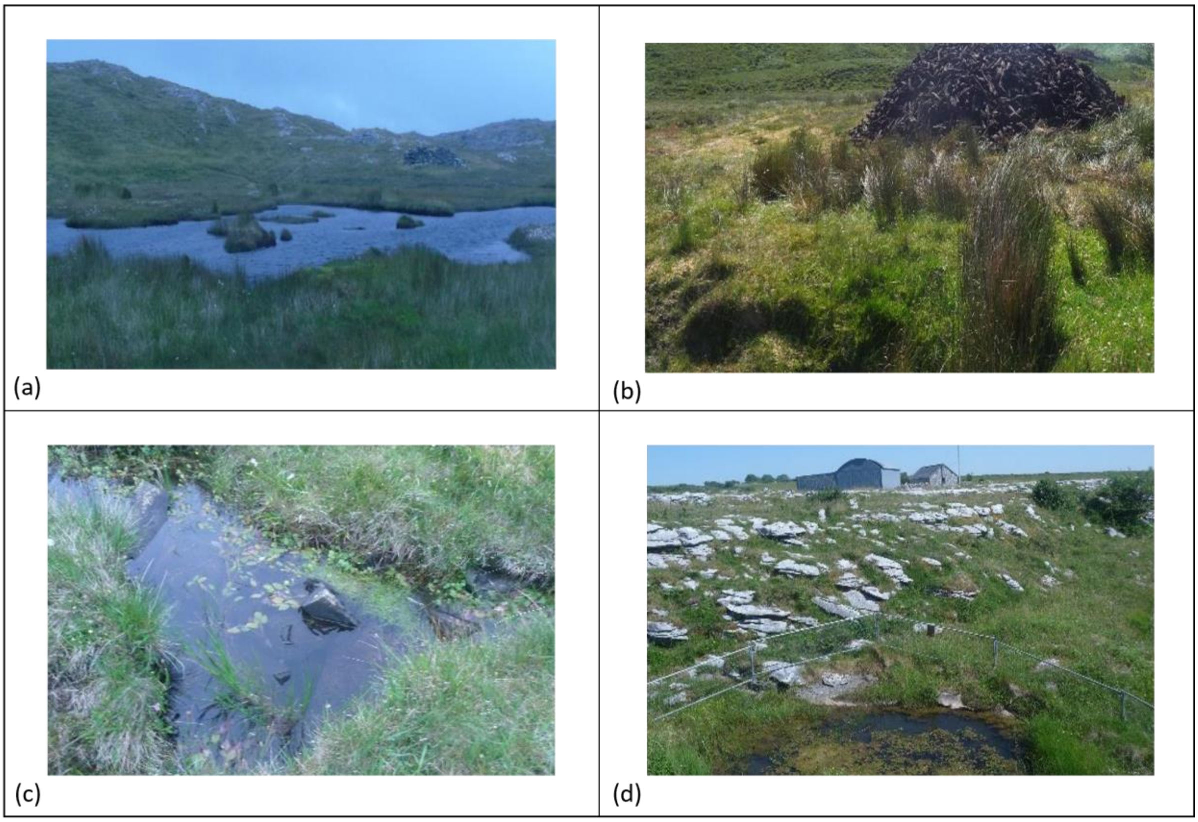

Figure 1.5: Types of wetlands (a) marshes; (b) harvested peat on peat flat; (c) fen; (d) bogs – facilitators encouraged to use national pictures (Photographs, Ryan S. Mohammed, Ireland).

(b) Lakes

Lakes are deep bodies of water with usually no direct connection to the sea, and which show stratification in terms of temperature, oxygen and nutrients. They may be both fresh and saltwater (e.g. the Caspian Sea is a saltwater lake, figure 1.6(a)). Most of the surface fresh water on the planet (1.2 million km^3 or 0.009 per cent of the total water on the Earth; figure 1.1) is housed in the major lakes of the world. Lakes can have different origins (see figure 1.6). Most are geological; however, some lakes are organic basins, which are the result of the activity of living organisms (including plant growth, deposition of detritus or activity of beavers for example). Others are human-made or induced (by dams).

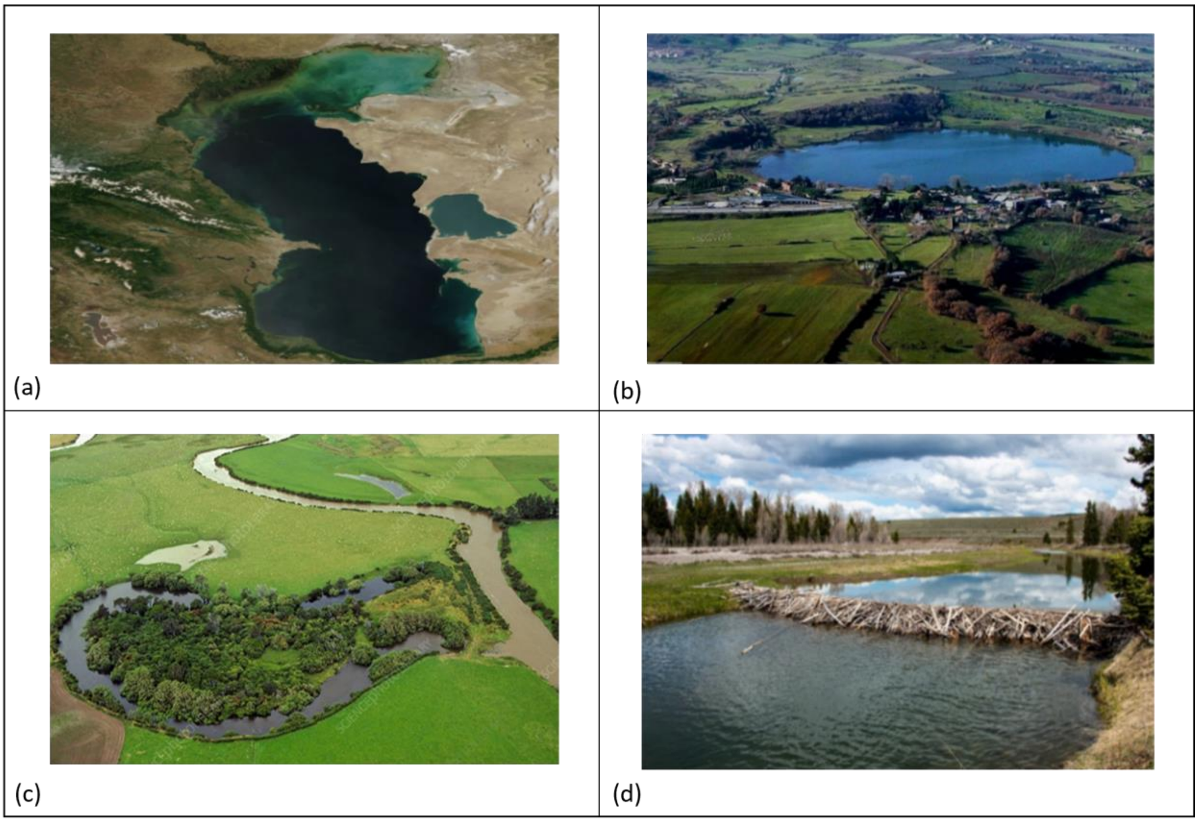

Figure 1.6: Types of basin lakes (a) satellite image of the Caspian Sea (https://upload.wikimedia.org/wikipedia/commons/thumb/9/98/Caspian_Sea_from_orbit.jpg/1200px-Caspian_Sea_from_orbit.jpg); (b) meteor basin, Lago di Monterosi, Italy (www.settemuse.it/viaggi_italia_lazio/VT_lago_monterosi/foto_lago_monterosi_010.JPG); (c) organic oxbow lake formed from meander cut-off (https://media.sciencephoto.com/image/c0056678/800wm/C0056678Aerial_view_of_an_oxbow_lake.jpg); (d) beaver dam (https://cdn.ecohustler.com/media/2020/01/15/beaver_dam.jpg).

D. Dynamics of changes of freshwater ecosystems and threats

Freshwater ecosystems are impacted by human activities and many are highly degraded. The UN Water Synthesis report on SDG 6 (UN-Water, 2018) emphasized that, over the past 40 years, freshwater species populations have declined by 80 per cent – more than double the rates seen in species both on land and in the oceans. At the same time, the world has lost 70 per cent of its natural wetland extent, including a significant loss of freshwater species, over the last 100 years, while artificial waterbodies, such as reservoirs, dams and rice paddies, have been increasing in most regions of the world. Compounding this loss of extent, it is estimated that 80 per cent of wastewater worldwide is dumped directly back into waterbodies completely untreated, leading to serious ecosystem and human health impacts.

1. Assessing the status of freshwater ecosystems

There are different ways to assess the status of water-related ecosystems, including extent, quantity of water, quality, habitat and biology. Box 1.1 presents the indicator adopted at the global level under the SDG framework.

Box 1.1: SDG indicator 6.6.1

SDG target 6.6 specifically aims to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes. Monitoring progress on target 6.6 uses one global indicator, indicator 6.6.1, change in the extent of water-related ecosystems over time, which provides important data for countries to take action. The indicator aims to monitor four main categories of ecosystems: vegetated wetlands (including swamps, swamp forests, marshes, paddies, peatlands and mangroves), open waterbodies (such as lakes and reservoirs), rivers and estuaries, and groundwater, while four sub-indicators (spatial extent, water quantity, water quality and ecosystem health) describe different aspects of these ecosystems. Due to data limitations, the main data available currently at the global level is on change in spatial extent of open waterbodies.

The Freshwater Ecosystems Explorer (www.sdg661.app/) has global-level data on ecosystems that is used to monitor SDG indicator 6.6.1. In addition, specific assessments of the status of freshwater ecosystems may be available in country or at subnational or local scales. In some cases, overview assessments might also already exist, that would identify freshwater ecosystems for example as natural/largely natural/moderately disturbed/largely disturbed/or seriously disturbed, and which can help guide action. Further guidance on the features and applications of the platform will be discussed in module 4.

Contextualization (optional): what is the status of freshwater ecosystems in your country?

2. Pressures on freshwater ecosystems and their drivers

Pressures that affect the condition of freshwater ecosystems can include the following (adapted from UNEP, 2017):

- Water infrastructure (e.g. dams and levees)
- Flow alteration (e.g. water withdrawals and diversions, reservoir operation)
- Modification of aquatic habitat and land-use change (e.g. urbanization or conversion of land to agricultural production)
- Overexploitation (e.g. overfishing or hunting, excessive water withdrawal or sand mining)
- Biological water pollution (e.g. invasive species)
- Chemical water pollution (e.g. agricultural or urban run-off or untreated wastewater)
- Thermal water pollution

These pressures and their drivers are themselves dynamic and evolving over time, due primarily to socioeconomic evolutions and climate change.

Figure 1.7, adapted from *Global Wetland Outlook*, 2018, presents types of pressures influencing changes in different wetland types.

Figure 1.7: Pressures effecting change in natural wetlands. Adapted from Ramsar Convention on Wetlands, Global Wetland Outlook: State of the World's Wetlands and their Services to People (Gland, Switzerland: Ramsar Convention Secretariat, 2018) www.global-wetland-outlook.ramsar.org/.

3. A framework for understanding ecosystem state, pressures, drivers of change and impacts

As noted previously, the interaction between freshwater ecosystems and human societies drives changes in freshwater ecosystems. These changes can result in both positive and negative impacts on ecosystems, and thus also on the services they provide. Understanding these linkages and potential direction of change is key to the sustainable management of freshwater ecosystems, where both threats and potential levers of change can be identified.

A reference framework for such analysis is the Driver-Pressure-State-Impact-Response Framework (DPSIR) (figure 1.8). It is a causal framework for describing the interactions between society and the environment and is used to assess and manage environmental problems (Gupta et al., 2020).

Each of the various components of the DPSIR framework are described below:

- "Drivers" are the underlying causes of environmental change that are external to the system or region in question, for example climate and socioeconomic change, regional, national and international policy. They reflect either the past, present or future conditions that cause changes to ecosystems.
- "Pressures" are the variables that quantify the effect of drivers within a system or region, for example temperature, precipitation, land cover, regional population, per capita water demand, crop prices or gross margins, and are usually assessed by developing regional, quantitative scenarios.
- "State" variables represent the sensitivity of the system/sector to the pressure variables. This involves the definition and quantification of all those elements relevant to the supply of the ecosystem service by biological organisms and the demand for ecosystem services from people. States are made up of variables that describe the whole of the social-ecological system, including the attributes of the ecosystem service beneficiaries and the attributes of the ecosystem service providers. These are tangible elements.
- "Impact" is a measure of whether the changes in the state variables have a negative or positive effect on individuals, society and/or environmental resources. In the framework presented here the negative or positive effects are measured in terms of the capacity to provide a given service.
- "Responses" through planned policy and management aim to minimize negative impacts (or maximize positive impacts/benefits) by acting on the socioeconomic pressure variables or directly on the state variables.

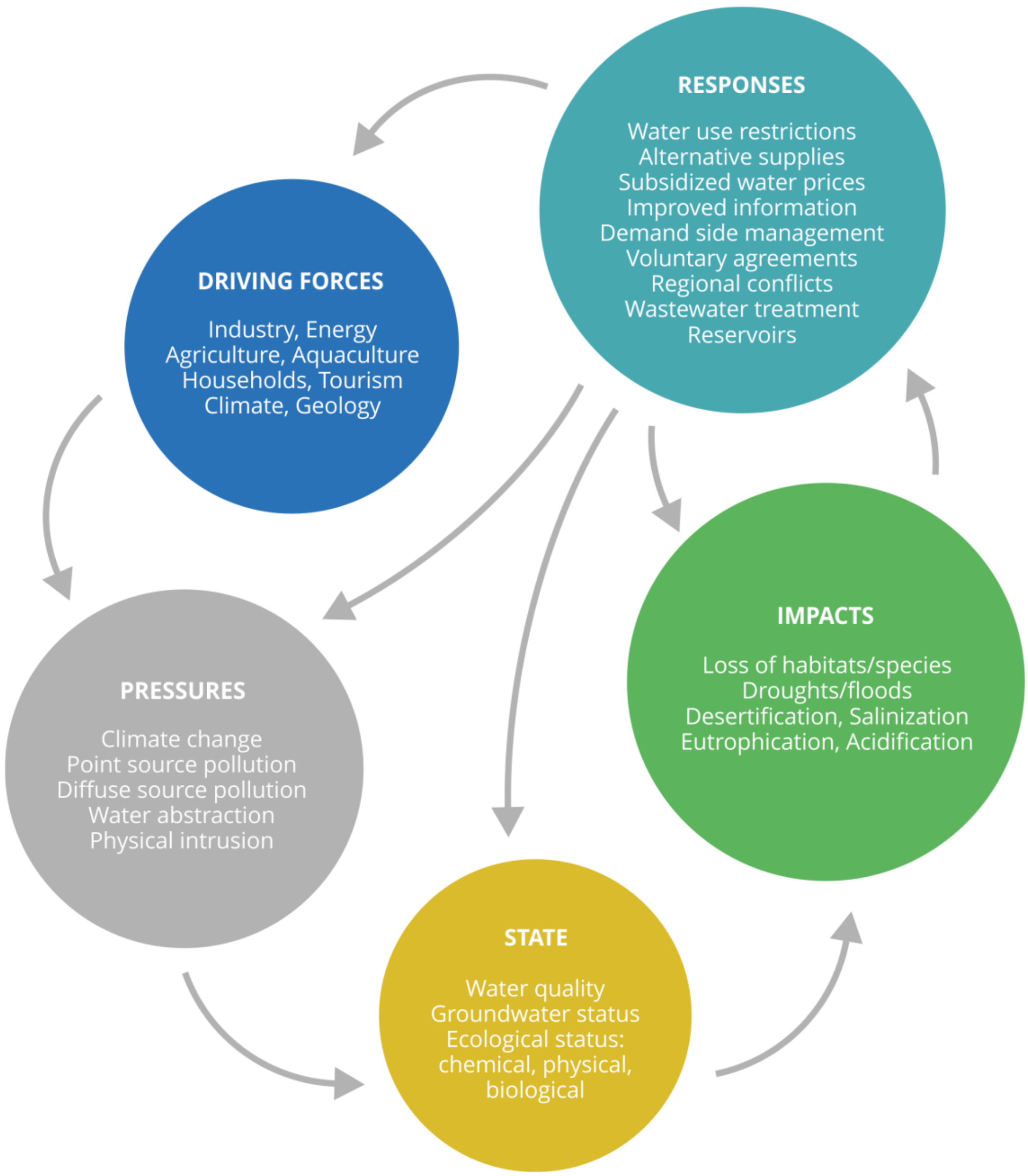

Figure 1.8: DPSIR framework. Source: Gupta et al. (2020).

Establishing a comprehensive DPSIR framework is a complex task as all the various cause-effect relationships should be identified and described, and environmental change can very rarely be attributed to a single cause. This "Framework for thinking", however, is useful in applying structure to the respective management approaches and helps identify drivers and levers of change as well as possible action pathways.

Contextualization: What are the pressures, drivers and trends that change freshwater ecosystems within your country/region/basin/province? Provide an example of DPSIR analysis relevant to your country/region/basin/province.

Example of DPSIR analysis: Gari et al. (2018).

E. Freshwater ecosystem services

Defining and understanding the different types of services provided by freshwater ecosystems provides insight into the importance of their effective management. To achieve sustainable development while managing freshwater ecosystem mobilization of stakeholders is key for its protection and restoration.

While different frameworks exist (see in particular UNESCO, 2021, section 2.3), we are sharing here a key reference framework for understanding and analysing ecosystems services, developed under the Millennium Ecosystem Assessment (MA). Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems (including freshwater systems) and their contribution to human well-being. It also helped to show that the capacity of these freshwater habitats to produce these services is in decline, and highlighted the need for action.

1. Ecosystem services provided by freshwater systems based on the Millennium Ecosystem Assessment

Ecosystem services are defined as the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life. The services provided by freshwater ecosystems can be categorized as follows:

Provisioning:

- Food – production of fish, wild game, fruits, grains
- Fresh water – storage and retention of water for domestic, industrial and agricultural use
- Fibre and fuel – production of logs, fuelwood, peat, fodder
- Biochemical extraction – of materials from biota
- Genetic materials – medicine, genes for resistance to plant pathogens, ornamental species
- Biodiversity – species and gene pools

Regulating:

- Climate regulation – greenhouse gases, temperature, precipitation; chemical composition of the atmosphere
- Hydrological flows – groundwater recharge and discharge; storage of water for agriculture or industry
- Pollution control and detoxification – retention, recovery and removal of excess nutrients and pollutants
- Erosion-retention of soils
- Natural hazards – flood control, storm protection

Cultural link to freshwater ecosystems:

- Spiritual and inspirational – personal feelings and well-being
- Recreational – opportunities for recreational activities

- Aesthetic – appreciation of natural features
- Educational – opportunities for formal and informal education and training
- Religious – rituals and ceremonies

Due to the variety of their biological, physical and chemical characteristics, different freshwater ecosystem types provide different kinds of services. UNEP, in its *Framework for Freshwater Ecosystems Management* (2017), provided an overview of the breadth of the types of ecosystem services that may be provided by a broad category of ecosystem type (see table 1.1). While each ecosystem type has the potential to provide most ecosystem services, whether they do or not depends on national and local conditions.

Category	**Type of service**	**Ecosystem type**					
		Rivers	**Riparian zones**	**Wetlands**	**Lakes**	**Estuaries**	**Groundwater**
Provisioning	Food	X	X	X	X	X	-
	Water	X	X	X	X	X	X
	Raw materials	X	X	X	-	-	-
	Genetic resources	X	X	X	X	X	-
	Medicinal resources	X	X	X	X	X	-
Regulatory	Air quality regulation	X	X	X	X	X	-
	Climate	-	X	X	X	-	-
	Water flows	X	X	X	X	X	X
	Wastewater	X	X	X	X	X	-
	Erosion prevention	-	X	X	-	X	-
	Maintenance of soil fertility	X	X	X	-	-	-
	Pollination	-	X	X	X	X	-
	Biological control	X	X	X	X	X	-
Habitat	Maintenance of species life cycles	X	X	X	X	X	-
	Maintenance of genetic diversity	X	X	X	X	X	X
Cultural	Recreation and mental and physical health	X	X	X	X	X	X
	Tourism	X	X	X	X	X	X
	Aesthetic appreciation and inspiration for art, culture and design	X	X	X	X	X	-
	Spiritual experiences and sense of place	X	X	X	X	X	X

Table 1.1: Examples of ecosystem services potentially provided by broad ecosystem types. Source: Framework for Ecosystems Management (UNEP, 2017).

Contextualization: Provide examples of ecosystems services provided by some freshwater ecosystems in your country (or other scales such as region, basin, province as relevant)

2. Perspectives on ecosystem services valuation

The identification of freshwater ecosystems services and their valuation can greatly contribute to their protection and restoration. Valuation can help assess the contribution that ecosystems make to human well-being. Additionally, it supports the sharing of perspectives of stakeholders on the benefits of protecting ecosystems and approaches to do so. Lastly it can help decision makers understand the incentives at play when managing ecosystems in different ways and understand the potential benefits to be derived from alternative courses of action.

Economic valuation of freshwater ecosystems remains a key tool for decision-making, though it is important to have in mind that their value resides in multiple dimensions – including notably economic, cultural, spiritual, emotional and environmental dimensions. As highlighted in the United Nations World Water Development Report 2021 "Valuing Water" (UNESCO, 2021), recognizing, measuring and expressing water's worth, and incorporating it into decision-making, are fundamental to achieving sustainable and equitable water resources management and the SDGs. "Value" means different things to various user groups and stakeholders and it is important, through the decision-making process, that the different values of water are reconciled, and the trade-offs between them resolved and incorporated in a systematic and inclusive manner.

(a) Methods for economic valuation of freshwater ecosystem services

As mentioned previously, freshwater ecosystems provide many diverse goods and services to human society. Many of the goods and services that may be provided by freshwater ecosystems globally today are not bought or sold and, thus, have no readily observable price tag. Any economic value attached to these goods or services must be estimated using a surrogate for the observable behaviours witnessed in the marketplace.

Available methods for the quantitative valuation of surface freshwater ecosystems require expertise from both social and natural sciences. Traditionally, pricing approaches make use of "real world" market-derived data to establish a monetary value. This is relatively easy for goods and services that are traded in commercial markets (such as supply of drinking water or energy) but is more difficult for services that are not (such as landscape quality).

More comprehensive valuation methods exist, including for example the Total Economic Value (TEV) (Loomis et al., 2000; Tinch et al., 2019). The approach includes the Use Value system as well as the Non-Use Value system. Use Value includes (i) direct use, (ii) indirect use, and (iii) the opportunity to use a resource. The Non-use Value includes (i) the value of a resource's existence and (ii) the benefit of the resource to others. Direct use value can pertain to extractive resources such as fish and water while indirect use value could be the provision of nursery services for juvenile fish, while the opportunity to use these ecosystem resources for recreational fishing also has a monetary value without actually extracting water. The non-use value system addresses the willingness to pay to experience the ecosystem and also to allow for the existence of it for future generations. The non-use value typically focuses on non-tangible resources.

The World Water Development Report 2021 (UNESCO, 2021), sections 2.3 and 2.4, provides a good overview of the state of the art on economic valuation of nature's contribution to people and ecosystems services.

Often, within the decision-making process, it is not possible to carry out an economic valuation of ecosystem services. In those cases, it can be useful to look for existing estimates, in relatively similar contexts, of the value of ecosystems services, and use those as references to illustrate the potential value of the services and inform and enhance the dialogue around the protection and restoration of freshwater ecosystems.

Box 1.2: Examples of valuations at different scales

At the global level, for example, Costanza et al. (2014) quantified global loss of ecosystem services due to land-use change and found that it amounted to $4.3 trillion–$20.2 trillion/yr. The same study found that ecosystem services contribute more than twice as much to human well-being as global GDP. Dynamics of change thus entail a tremendous loss of services coupled to a subsequent increase in the cost of existing services.

As part of the development of a watershed management plan for Lake Ohrid, shared between Albania and North Macedonia, an ecosystem services valuation was realized in 2017. The value of the ecosystem services provided by the lake was estimated at more than $60 million for provisioning services only, and the value of services of the whole watershed was also estimated. This valuation was one of the key inputs to the development of the watershed management plan.[2]

Finally, it is also useful to mention that progress is being made more broadly for the development and structuration of ecosystem accounting. In particular, the United Nations Statistical Commission adopted in March 2021 the System of Environmental Economic Accounting: Ecosystem Accounting (SEEA EA). The SEEA EA is an integrated and comprehensive statistical framework for organizing data about habitats and landscapes, measuring ecosystem services, tracking changes in ecosystem assets, and linking this information to economic and other human activity. Data on freshwater ecosystems, including information on ecosystem extent and condition, ecosystems services and their valuation can contribute to development of SEEA EA. Conversely, strides being made on SEEA EA can provide important information to decision makers and

[2] See https://www.gwp.org/en/GWP-Mediterranean/WE-ACT/News-List-Page/2021/valuing-lake-ohrid/#:~:text=The%20total%20value%20%E2%80%93%20expressed%20in,watershed%2C%20equals%20%242%2C102%2Fha.

practitioners for policy planning, cost-benefit analysis, or for raising awareness of the importance of nature to society.

(b) The business case for protection of freshwater ecosystems

A business case lays out the arguments for action. It can be addressed to different categories of actors, including policymakers, stakeholders or businesses. Its content might include for example background information, expected benefits of action – particularly for the actors targeted – potentially also the options considered, and expected costs and risks. A business case is not necessarily quantified (see, for example, *The Business Case for Adaptation* https://unfccc.int/sites/default/files/resource/businesscase.pdf), but valuation of services provided and of impacts of changes can greatly strengthen the case for action.

Contextualization: Example of relevant business case from the country (or other scales such as region, basin, province as relevant)

For example (other business cases may be shared in country): Nairobi (The Nature Conservancy, 2015), Camboriú (in Brazil, but would be relevant for Argentina; Kroeger et al., 2017).

F. Conclusion – towards action

As apparent from the types of ecosystems services, pressures and drivers, freshwater ecosystems are embedded in complex national, socioeconomic and institutional systems. Their status is profoundly affected by socioeconomic evolutions, including for example agricultural intensification, industrialization or urbanization. In turn, the changes in freshwater ecosystems can also affect those processes; for example, increased risks of floods linked to reductions in wetlands areas may affect human activities. An intersectoral approach that engages all relevant stakeholders and mobilizes systems thinking is thus paramount for action. Module 2 will present key steps towards the development of an action plan for the protection and restoration of freshwater ecosystems.

Mandatory reading

1. UN-Water. SDG 6 Synthesis Report on Water and Sanitation. Geneva, 2018.
    - Section on Target 6.6 (pp. 87–92). Available at www.unwater.org/publications/sdg-6-synthesis-report-2018-on-water-and-sanitation/.

Recommended reading

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2. UNEP. Case story presenting example of status of a freshwater ecosystem and pressures, 2021. Available at https://stories.sdg661.app/#/story/1/0/0
3. United Nations Environment Programme (2021). Progress on freshwater ecosystems: tracking SDG 6 series – global indicator 6.6.1 updates and acceleration needs. Executive Summary. Available at https://www.unwater.org/publications/progress-on-water-related-ecosystems-661-2021-update/
4. UNESCO World Water Assessment Programme. *United Nations World Water Development Report 2021: Valuing Water*. Paris, 2021. Available at www.unwater.org/publications/un-world-water-development-report-2021/
    - Executive summary
    - Sections 2.3 "Valuing the environment" and 2.4 "Methods used to calculate values"
5. The Nature Conservancy. Guidance on developing a business case. TNC Water Funds Toolbox. Available at https://waterfundstoolbox.org/project-cycle/design/design-studies/business-case

Recommended websites

1. SDG 661 Freshwater Ecosystems Explorer: www.sdg661.app/

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2. Bunn, S.E. and A.H. Arthington (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management*, vol. 30, No. 4, pp. 492–507.
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5. Gupta, J., and others (2020). Re-imagining the driver–pressure–state–impact–response framework from an equity and inclusive development perspective. *Sustainability Science*, vol. 15, No. 2, pp. 503–520.
6. Kroeger T., and others (2017). *Assessing the Return on Investment in Watershed Conservation: Best Practices Approach and Case Study for the Rio Camboriú PWS Program, Santa Catarina, Brazil.* Arlington, VA: The Nature Conservancy. Available at https://s3.amazonaws.com/tnc-craft/library/BrazilWaterROI_English.pdf?mtime=20180218180102
7. Loomis, J., and others (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological Economics*, vol. 33, No. 1, pp. 103–117.

8. The Nature Conservancy (2015). *Upper Tana-Nairobi Water Fund: A Business Case*. Version 2. Nairobi, Kenya: TNC. Available at https://s3.amazonaws.com/tnc-craft/library/upper-tana-nairobi-water-fund-business-case.pdf?mtime=20180115013122
9. Tinch, R., and others (2019). Economic valuation of ecosystem goods and services: a review for decision makers. *Journal of Environmental Economics and Policy*, vol. 8, No. 4, pp. 359–378.
10. United Nations Educational, Scientific and Cultural Organization (2021). *United Nations World Water Development Report 2021: Valuing Water*. Paris: UNESCO World Water Assessment Programme.
11. United Nations Environment Programme (2017). *A Framework for Freshwater Ecosystem Management*. Nairobi: UNEP.
12. United Nations Water (2018). *SDG 6 Synthesis Report on Water and Sanitation*. Geneva: UN-Water.

Module 2: Protecting and restoring freshwater ecosystems

A. Goal

This module aims to provide an understanding of the processes that can be employed in identification of priority freshwater ecosystems and developing action plans to preserve and/or restore those ecosystems.1

Learning objectives

Upon completion of this module, participants should show a good understanding of the:

- Scope, scale and principles of freshwater ecosystems action planning
- Situation analysis, stakeholder analysis and design of the action planning process
- Initial engagement with stakeholders and identification of priority freshwater ecosystems
- Action plan development through a multi-stakeholder engagement process
- Implementing, monitoring, evaluating and learning
- Conclusion and importance of data

B. Introduction

Freshwater ecosystems such as lakes, rivers, wetlands and aquifers are indispensable for life on our planet. Module 1 highlighted how they are essential for sustainable development and human well-being through the services they provide, including some of the pressures and threats they face. Dedicated action to protect and restore them is needed, to support a sustainable future for people, environment and the economy.

One approach to action planning consists of a relatively rapid process aiming to identify catalytic actions that can help drive change, identified through a multi-stakeholder engagement process. This helps demonstrate impact and catalyse further action. The module also identifies how the process might be enhanced at different stages towards a more comprehensive action planning process.

C. Scope, scale and principles of freshwater ecosystems action planning

Freshwater ecosystems are profoundly affected by the interactions between human societies and the natural environment – for example through land-use changes, water withdrawals for human consumption and economic activities, pollution, or anthropogenic climate change.

The sustainable management of freshwater ecosystems requires recognition of the complex socioeconomic interactions that affect them, how they drive changes in ecosystem dynamics, what other alternatives or trade-offs can be identified to shift the dynamics, and what actions would potentially lead to those alternatives being viable options for the stakeholders who interact with the landscape. This approach must be carried out in a way that is fully aligned with legitimate interests of those stakeholders, whose views and perspectives should be fully integrated into any long-term objective.

We focus here on action planning which is carried out under the leadership of one or several mandated institutions, having the objective to protect and restore freshwater ecosystems while also responding to and aligning with broader development goals and policy frameworks of the country.

With regard to scope, emphasis is placed on two main components to action planning:

- Prioritization of freshwater ecosystems to protect and/or restore.
- Development of an action plan in the form of a concrete set of context-specific implementable interventions that provide responses to identified challenges. It should integrate the perspectives of different stakeholders during its formulation and validation, and be supported by the mandated institutions and also other relevant national and local government bodies.

The main objective of a rapid process is to identify priority areas of focus and catalytic interventions that can help drive change. As such, the action plan would highlight a short list of priority actions, which would be mainly short- to medium-term interventions, within a longer-term vision. It can be useful however to list separately longer-term actions that may be considered in the future, and the plan should strive to build mechanisms for sustained and more comprehensive action over time, as protection and restoration of freshwater ecosystems is a long-term process. The reason for focusing on shorter-term interventions (or "quick wins") is to provide proof of concept to improve the enabling environment for future interventions.

The approach described is geared towards action planning at national or subnational (provincial or watershed for example) scales, although it can be adapted for work at a lower scale including site-specific work.

Key principles in the approach are:

- Flexibility in implementation. Each country has unique political, economic, environmental, social and cultural conditions, which means that there is no one single approach that works for protecting and restoring freshwater ecosystems. The approach presented here is intended as a guide to ensure that key issues are considered rather than a set blueprint for the process.
- Systems thinking (see box 2.1) to identify and develop solutions that can effect change on drivers of pressures. This entails a strong focus on multisectoral and interdisciplinary approaches.

- Multi-stakeholder engagement to holistically and jointly identify issues and potential drivers of change, assess the benefits, knock-on effects and trade-offs, and increase support and buy-in for the actions identified.
- Building on defined national processes and priorities, to help ensure that the solutions contribute to meeting existing commitments, increasing resource efficiency and impact.
- Recognition and management of competing objectives. Freshwater ecosystem management often requires arbitrating between perceived trade-offs involving the needs for short-term socioeconomic development, which can put extra pressures on ecosystems, and the needs to protect and restore ecosystems to support more long-term, sustainable development. Identifying these competing objectives, maximizing synergies where possible, and ensuring a participatory and transparent decision-making process are key in this regard.
- Finding a balance between realism and ambition. The approach should strive to be ambitious in bringing about lasting and transformative change in the protection and restoration of freshwater ecosystems. At the same time, the approach should bring realism to the ambition by ground truthing the objectives into a process and actions that are feasible and achievable.

Box 2.1: Systems thinking for ecosystems management

Many problems we face today involve interdependent structures and multiple actors, and are at least partly the result of past actions. Such problems are extremely difficult to tackle and conventional solutions have very often led to unintended consequences. A systems thinking approach focuses on systems as a whole: how the parts interrelate and how interconnections create emerging patterns. Systems thinking tools allow us to map and explore dynamic complexity. With a better understanding of systems, we can identify leverage points that lead to desired outcomes and avoid unintended consequences.

Source: UNEP (2016).

To go further, two key references presenting different approaches to freshwater ecosystems management are shared as recommended reading:

- The UNEP *Framework for Freshwater Ecosystem Management* (2017)
- The Nature Conservancy *Beyond the Source* guide (Abell et al., 2017)

These are useful to practitioners to enhance their thinking on action planning towards freshwater ecosystems protection and restoration, and can inspire them to adapt their approaches.

D. Situation analysis, stakeholders' analysis and design of the action planning process

This section focuses on the initial data collection and analysis to carry out as well as the detailed design of the action planning process. These different components are not separate and feed into each other, in an iterative manner.

1. Situation analysis

In order to design activities to protect or restore freshwater ecosystems, it is necessary to understand their current status and importance, how they are evolving and why, and the broader enabling environment. Module 1 presented key frameworks for analysing freshwater ecosystems, dynamics of change and the systems in which they are embedded, including the Driver-Pressure-State-Impact-Response framework, an overview of the range of ecosystems services provided, and approaches to ecosystems valuation. In addition, it is fundamental to identify stakeholders concerned and map them.

Information should be collected on the following dimensions:

- Available knowledge on freshwater ecosystems in the country, including:
    - identification of freshwater ecosystems, including major or high-value ecosystems
    - ecological status
    - ecosystem services provided and, if available, their valuation and the case for protection and restoration
    - key pressures, drivers of these pressures (including those related to other sectors such as agriculture, land-use planning, urbanization or industrialization) and trends
    - climate change scenarios and their predicted impact on freshwater ecosystems
- Enabling environment:
    - institutional arrangements for protection and restoration, including institutional capacity and relations between institutions
    - relevant national or subnational priorities, policies, strategies, plans, laws
    - major ongoing programmes, projects, initiatives or commitments
    - existing financing mechanisms
    - capacity gaps, if they have been previously identified
- Identification of key stakeholders and stakeholders mapping (see below).
- Relevant available information on inequalities, with a particular focus on gender-specific inequalities, including those contributing to pressures on freshwater ecosystems, impacts of ecosystem degradation on the most vulnerable, socioeconomic barriers, access to resources, as well as issues related to participation and representation, to ensure attention to the most vulnerable and an inclusive approach.
- Major knowledge gaps regarding the above should be identified.

Module 3 explores the range of data sources which may be considered and how they may be analysed. Depending on resources available, the initial analysis might be carried out through a rapid desk review of major data sources, some key informant interviews, and possibly a survey of identified experts, or a more in-depth review and analysis might be carried out.

Finally, data collection and analysis should not stop at the initiation of the action planning process. Additional information and perspectives, as would come up in particular through stakeholder engagement, should be collected and taken into account throughout the process.

2. Importance of stakeholder engagement and stakeholders' analysis

"Stakeholder" defines individuals, groups and organizations who can affect or be affected by a specific issue. Considering how freshwater ecosystems are shaped by, and in turn have an impact on, multiple sectors and various groups of actors, stakeholder engagement is key to the sustainable management of freshwater ecosystems.

Effective and inclusive stakeholder engagement allows stakeholders to be involved in the decisions that affect them and presents multiple benefits, notably:

- Improved understanding of freshwater ecosystem management benefits, the systems at play, and of knock-on effects and trade-offs
- Improved planning and decision-making through consideration of stakeholder perspectives and development of mutually acceptable solutions with benefit gained by all
- Transparency and accountability
- Better buy-in and support of stakeholders to solutions identified, which increases likelihood of implementation and impact
- Confidence building and increased trust between different stakeholders

The following stakeholders should be considered for action planning on protection and restoration of freshwater ecosystems:

- Institutions at national and subnational (if relevant) level: representatives from mandated institution(s) responsible for freshwater ecosystems management, those from other institutions involved in or with an impact on freshwater ecosystems (e.g. agriculture/livestock, forestry, energy, environment, tourism, urban planning, sanitation, finance, climate change, risk management, health), river basin organizations.
- Scientific, academic and technological community: academic institutions, universities, research institutions, think tanks and other bodies who may have relevant information, studies, data and analyses on different aspects of freshwater ecosystems.
- Civil society: non-governmental organizations with a focus on freshwater ecosystems management, environmental organizations, grass-roots organizations, representatives of marginalized groups, including indigenous people, gender advocacy groups, youth-led organizations.

- Representatives of user groups and economic groups: water user groups, utilities, representatives of economic groups with a vested interest in freshwater ecosystems and their drivers of change, be they from the beverage, food, mining, energy, paper, consumer products, tourism or other related sectors.
- Development, financial and donor community: United Nations entities most relevant for sustainable development, the environment, social considerations and economic development, multilateral and bilateral donors and development banks, foundations, other financiers.
- The private sector as financiers: water-using companies that may be looking to contribute to Corporate Water Stewardship initiatives that meet their corporate social responsibility targets by restoring the ecosystems that contribute to water security for all stakeholders.

A stakeholder analysis, building on the identification of stakeholders, is key to designing an appropriate and effective engagement process. Different approaches are possible in this regard:

- A thorough stakeholder analysis enables the systematic identification, assessment and comparison of stakeholders' particular sets of interests, roles and powers, and the consideration and investigation of the relationships between them, including alliances, collaborations and inherent conflicts.
- As a more rapid approach, stakeholder mapping provides important insights into the identification and status of different stakeholders vis-à-vis freshwater ecosystem management. A common framework is categorizing stakeholders according to their interest and influence (figure 2.1). The engagement approach can then be tailored to each of these groups.

In the analysis, it is important to emphasize cross-sectoral thinking. Very often, stakeholders of high interest, whose actions have a strong impact on freshwater ecosystems, will be from other sectors, such as land-use planning, agriculture, urban development or energy.

	Stakeholder analysis grid		
Influence	**High power to influence change**	**Satisfy:** Medium-priority stakeholders that you will need to work with and engage as opportunities arise to impact Examples: Media, other NGOs and CSOs	**Influence:** High priority stakeholders that have the ability to impact and take decisions to support your overall advocacy objectives Examples: Policy-makers, local or national decision-makers, high level officials
	Little power to influence change	**Monitor:** Low priority stakeholders to involve only when resources permit or where there is potential added value to one of your objectives Examples: Local businesses affected by the issue	**Inform, consult and involve:** Medium-priority stakeholders that could be most affected by this issue, and would be beneficial to consult with and keep informed of your work Examples: Local communities and stakeholders that are impacted by the issues you cover
		Doesn't matter much to them and/or does not work closely on issues	**Matters a lot to them and/or works closely on issues**

Figure 2.1: Stakeholder analysis grid and example of engagement approach. (Source: Goal 16 Advocacy Toolkit, TAP Network, updated by UNESCAP, 2018).

Contextualization (optional): example of stakeholders involved in a prior initiative on Integrated Water Resources Management (IWRM) or environmental management and, if available, stakeholder mapping of these stakeholders

3. Design of the action planning development process

It is important to lay out the steps that will be taken for the development of the action plan, under the leadership of the key mandated institution(s). There is not one single approach to it and the design will depend on the objective(s) of the mandated institution(s), the resources available, the country context and opportunities it provides.

It may be, for example, that, after the initial analysis is carried out, a first set of consultations is carried out with stakeholders to discuss the analysis and agree on prioritization of freshwater ecosystems and on the scope and main objectives for the action plan. A smaller task force may then be tasked to identify potential actions, to be discussed during a second set of consultations, allowing the action plan to be matured. An intermediary consultation process may also be included to gather stakeholder perspectives on the range of potential actions to consider.

When feasible, the process can be constructed in a participatory manner with the stakeholders. In a rapid process, time or financial constraints might not allow for this; it will be important, however, to present the approach to stakeholders and be open to their feedback and suggestions.

The design should consider the following points:

- Timeframe for the development of the action plan
- Resources available
- Objectives of the action planning process for the lead mandated institutions
- Scope, including for example a focus on a short list of priority actions to be implemented over the short to medium term
- Ownership: The appropriate mandated authorities should take the final decisions on content of the plan based on the views presented by all stakeholders (including dissenting views)
- Roles, responsibilities and activities in the process
- Effective stakeholder engagement strategies
- Biodiversity strategies
- Alignment with relevant ongoing processes, which might be for example on IWRM, environmental management, biodiversity strategies, climate adaptation or national and subnational planning

Contextualization: example of action plan process or stakeholder engagement strategy implemented in a prior initiative for IWRM or environmental management

4. Initial engagement with stakeholders and identification of priority freshwater ecosystems for protection and restoration

Engagement with stakeholders at the initial stages is important to build a shared understanding around the status of freshwater ecosystems, their importance, including the services they provide, the threats they are facing, pressures and the drivers of pressures, and their trends of evolution. When available, the valuation of ecosystems services or business cases for protection and restoration can also usefully be shared. This initial engagement can take the form of bilateral or small group meetings with key stakeholders (for example key institutions such as ministries of finance and planning) or of an online or virtual workshop (which can be combined with the prioritization of freshwater ecosystems, see below). It is also an opportunity to discuss with the stakeholders the envisaged process to action planning.

In a context of constrained resources, prioritization of freshwater ecosystems to be protected and restored is an important part of action planning. The prioritization of ecosystem(s) needs to build on the knowledge available and must be carried out with stakeholders. A multi-criteria approach is recommended, which may consider the following criteria in particular:

- Importance of ecosystem services provided
- Status of the freshwater ecosystems being considered (for example natural/largely natural/moderately disturbed/largely disturbed/or seriously disturbed)
- Level of risks of further degradation in the future, stemming from pressures, drivers and trends

Depending on resources available, a rapid, simple approach for the prioritization may be based on a qualitative assessment of the key criteria, based on the initial analysis, and with a focus on the major freshwater ecosystems pre-identified (see box 2.2 for an example), followed by a scoring. Stakeholder engagement can include a stakeholder workshop, and potentially additional bilateral or small group interviews or consultations.

For the scoring, it is important to have in mind that the process entails choices about what criteria to prioritize, which should be discussed with stakeholders: for example, should ecosystems that are already very highly degraded, with limited likelihood of recovery given existing trends, be prioritized? Or should the priorities be on those ecosystems that appear to have better dynamics? And what about ecosystems that are not currently altered, but which may face future threats?

Box 2.2: Example of multi-criteria qualitative assessment

	Ecosystems services provided	Status of ecosystem	Level of risks faced
Ecosystem 1	High	Natural	High
Ecosystem 2	Low	Seriously disturbed	Medium
Ecosystem 3	Medium	Largely disturbed	Low
....			

Depending on the knowledge base and availability of time, the approach can be enhanced through a more in-depth analysis and scoring, through the use of GIS-mapping, and through a more extensive stakeholder engagement process.

5. Action plan development through a multi-stakeholder engagement process

Earlier in this module we shared an overview of what the action plan would be: a set of context-specific implementable and priority interventions that provide responses to identified challenges.

The action plan should include the following:

- List of actions identified, the responsible actor(s), target timeline, delivery mechanism, required resources and, when possible, available funding sources (see box 2.3 for an example of presentation)
- Planned mechanism(s) for coordination of implementation of the action plan and for monitoring, evaluation and learning in implementation

Box 2.3: Example presentation of an action plan

Priority actions	Responsibility	Timeline		Delivery mechanism	Resources required	Budget
		Start	End			

We present below key steps to consider in the development of the action plan.

(a) Step 1: Defining scope and objectives of the action plan

A first step is defining, under the leadership of the key mandated institution(s) and with stakeholders, the scope and objectives of the action plan.

In terms of scope:

- The geographical scope may be regional, national, subnational, basin level or site specific. It should take into account the outcomes of the prioritization exercise.
- The thematic scope should be open to all drivers of pressures and sectors influencing the status and evolution of freshwater ecosystems. It is important to recognize explicitly the multisectoral nature of the action plan, to design interventions that can be effective at making change happen. Interventions may have to mobilize non-water stakeholders, beyond the typical scope of mandated institutions, thus requiring the involvement in the process of the relevant bodies for those stakeholder groups (for example agriculture ministries, city planners).

The objectives of the action plan may include elements such as (not exclusive from one another):

- Preventing further deterioration of ecosystems at the scale in focus
- Promoting sustainable management and use of ecosystems
- Protecting high-value ecosystems
- Restoring degraded ecosystems
- Ensuring alignment with broader policy frameworks and enhancing ecosystems contributions to meeting various national, regional and global targets

The engagement of stakeholders on the definition of scope and objectives can be included as a final part to a prioritization workshop, or be undertaken at a later, separate time. Final decision-making on the scope and objectives lies with the mandated institution(s) leading the process.

If resources allow, it is useful to plan a joint visioning exercise with stakeholders. In a visioning process individuals and groups develop a vision for the future, which helps to answer the question: “What do we want to see in place 5–10 years from now?” Having developed a shared vision, stakeholders then go through a process of “back casting” to translate the vision into more concrete goals and actions.

Box 2.4: Benefits of visioning

By engaging participants in the formulation of a common goal, visioning gives people a sense of control and motivation, and offers a possibility for fundamental change. With problem solving, a group can become mired in technical details and political problems and may even disagree on how to define the problem. Visioning provides a positive paradigm by offering something to move towards. It offers a bigger picture. It generates creative thinking and passion to solve the problems that might arise when moving towards a vision.

Adapted from the Multi-Stakeholder Partnerships website

(b) Step 2: Identifying most pressing challenges, key levers of changes, potential solutions and priority interventions

Key issues and barriers to preservation and/or restoration shall be identified with the stakeholders (considering in particular drivers of pressures on the ecosystem(s)), followed by identification of key levers of change, potential solutions and priority implementable interventions.

This should be informed by the situation analysis and should be developed with stakeholders. As in the previous step, stakeholder engagement can take the form of a consultation workshop and additional bilateral or small group consultations. A smaller task force can also usefully be convened to enhance the process and deepen the thinking.

Once potential solutions have been identified, it is useful to start developing them by reflecting about what their means of implementation would entail and their potential impact. Not all solutions for a given problem have the potential to be implemented, or maybe implementation is not feasible given the time and budget projected. Prioritization can then be based on a consideration of the two dimensions of (i) feasibility of implementation and (ii) potential impact.

The interventions may be of different natures and at different scales, including for example interventions related to governance and to the enabling environment, financial innovations, or targeted management and remediation projects and field-level interventions. The interventions should cover key relevant sectors identified, such as agriculture or infrastructure planning.

With regard to the enabling environment, interventions may include, for example, reviews or preparation of legislative frameworks, policy and strategy documents, alignment with other ecosystem-based objectives, governance systems and means of increasing stakeholder participation, institutional strengthening, monitoring and data management systems.

Examples of field-level interventions are presented in box 2.5.

Box 2.5: Example of field-level interventions

- Conservation activities undertaken to protect targeted ecosystems
- Revegetation and restoration of riparian vegetation
- Wetland restoration and creation
- Changes in agricultural cropping practices through cover crops, conservation tillage, precision fertilizer application, irrigation efficiency, contour farming and agroforestry
- Ranching best management practices
- Techniques to reduce the environmental impacts of roads, through reduction of erosion or improved road-stream crossings

Adapted from Abell et al., (2017, p. 39).

Lead entities for the implementation of each action should be identified, with their prior agreement. These may be, for example, a department in a sectoral ministry, or the ministries of finance and planning.

The definition of the interventions will depend on the geographical scope of the action plan and should consider:

- The freshwater ecosystem(s) prioritized.
- How the interventions could overcome the identified issues and barriers.
- The level of institutional capacity needed to implement the activities.
- The interlinkages and synergies with other priorities, strategies and plans, in particular those related to IWRM and SDG 6.5.1, to the climate agenda, and other SDGs.
- Gender sensitivity and inclusion concerns, to be considered to the extent possible. The action plan should strive to ensure that no activities negatively impact women or marginalized groups.
- The availability of funding and alignment with other key delivery mechanisms.

The presentation and delivery mechanisms for the identified activities can take a variety of forms depending on how each of the activities has been defined and the interlinkages with other processes and initiatives. Examples include:

- Preparation and implementation of community-level action plans.
- Implementation of field-level interventions, including for example wetland restoration, reforestation or adoption of ranching best management practices.
- Inputs to existing plans, programmes, project documents or similar, incorporating the activities identified.
- Formal written input to an ongoing SDG or national development process such as a broader SDG 6 action plan, a National Adaptation Plan, the Nationally Determined Contributions, a national strategy in response to global biodiversity goals or local development plans.

Contextualization: example of actions identified for IWRM or environmental management under previous action planning processes

(c) Step 3: Finalization and endorsement of the action plan

It is important that the identification of priority ecosystems and action plans is supported by the corresponding authorities, concerned institutions and stakeholders. The support and endorsement might be expressed for example through administrative acts, the adoption of the list of prioritized ecosystems and action plan at the closing of stakeholder workshops and/or through a dedicated high-level event.

Formal endorsement by the government and stakeholders is key to ensure lasting impact. It is recommended in particular that the action plan is brought into a formal document that shall be officially endorsed by the government, to ensure that the plan may be implemented by the mandated institution(s). The degree of institutional formalization will depend upon the circumstances of the country in question but may include the publication and approval on relevant national-level SDG coordination platforms, in national forums, or by any other means that can facilitate its later implementation. Ideally the action plan should also be officially supported by other institutions that commit to contribute to its achievement.

E. Implementing, monitoring, evaluating and learning

The success of the action plan lies in its implementation. We highlighted throughout the process description above key points of attention to increase the likelihood of implementation, which we can summarize as follows:

- Mandated institution(s) and stakeholders buy-in, support and endorsement.
- Clear definition of the actions and identification of lead implementing entities and of the roles of different institutions.
- Alignment between the actions and ongoing processes, initiatives and programme where relevant.
- Definition, in the action plan, of the planned mechanism(s) for coordination of implementation of the action plan and for monitoring, evaluation and learning in implementation.
- Identification of a main institution or group that will be in charge of coordinating implementation of the action plan.
- Identification of mechanisms for communication and dissemination of the plan.

The approach to monitoring, evaluation and learning should be designed at the same time as the action plan is developed. It should:

- Allow implementation of the activities to be overseen.
- Provide pointers to assess the impacts of the implementation of the action plan (which might be in a qualitative manner through key informant interviews, for example, or in a quantitative manner through assessment of quantitative indicators when feasible) so that lessons can be learned.
- Support follow-up engagement with stakeholders to discuss progress in implementation, impact and lessons learned, and adjustments to make to the approach.
- Support adaptive management.

F. Conclusion and importance of data

In this module, we have shared with the practitioner guidance on action planning for the protection and restoration of freshwater ecosystems through a rapid process that enables the identification of catalytic actions which can effect change. Throughout the process, data is paramount: for developing an initial understanding of the issues, of the systems at play and of stakeholders involved; for supporting the discussions with stakeholders and identification of potential solutions; for identifying interventions to prioritize; and for informed decision-making. Module 3 will take the practitioner through key data sources and data analysis techniques which can be applied in this regard.

Recommended reading

1. United Nations Environment Programme. *A Framework for Freshwater Ecosystem Management*. Nairobi: UNEP, 2017. Available at www.unep.org/resources/publication/framework-freshwater-ecosystem-management
    - Pages 5–19: Volume 1: Overview and country guide for implementation; Part 2. Summary and Part 3. Phases and steps
2. Abell, Robin, and others. *Beyond the Source: The Environmental, Economic and Community Benefits of Source Water Protection*. Arlington, VA: The Nature Conservancy, 2017. Available at www.nature.org/content/dam/tnc/nature/en/documents/Beyond_The_Source_Full_Report_FinalV4.pdf. The reference provides an overview of the benefits of and the approach to source water protection through water funds.
    - Executive Summary
3. Bland, Lucie M., and others. Impacts of the IUCN Red List of Ecosystems on conservation policy and practice. *Conservation Letters*, vol. 12, No. 5, e12666 (2019). Available at https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/conl.12666
4. United Nations Economic and Social Commission for Asia and the Pacific. *Effective Stakeholder Engagement for the 2030 Agenda – Training Reference Material*, 2018. Available at https://sdghelpdesk.unescap.org/e-library/effective-stakeholder-engagement-2030-agenda-training-reference-material

- Module 1: Foundations. Pages 7–19.

5. AccountAbility, and others. *From Words to Action: The Stakeholder Engagement Manual*. London, 2005. Available at http://www.mas-business.com/docs/English%20Stakeholder%20Engagement%20Handbook.pdf
    - Volume 2: *The Practitioner's Handbook on Stakeholder Engagement*. Pages 96–109.

Recommended videos

1. About MSPs. Available from the About section of the Multi-Stakeholder Partnerships website (www.mspguide.org)
2. Water Fund videos. Available from Getting Started section of The Nature Conservancy Water Funds Toolbox website (https://waterfundstoolbox.org)
    - Rio de Janeiro Water Fund, Brazil. Also available at www.youtube.com/watch?v=S3tQTfAzysk&t=3s
    - Upper Tana-Nairobi Water Fund, Kenya. Also available at www.youtube.com/watch?v=RWDoBna3dvw

References

1. Abell, Robin, and others (2017). *Beyond the Source: The Environmental, Economic and Community Benefits of Source Water Protection*. Arlington, VA: The Nature Conservancy. Available at www.nature.org/content/dam/tnc/nature/en/documents/Beyond_The_Source_Full_Report_FinalV4.pdf
2. United Nations Economic and Social Commission for Asia and the Pacific (2018). *Effective Stakeholder Engagement for the 2030 Agenda – Training Reference Material*. Thailand: UNESCAP. Available at https://sdghelpdesk.unescap.org/e-library/effective-stakeholder-engagement-2030-agenda-training-reference-material
3. United Nations Environment Programme (2016). *Wicked Problems, Dynamic Solutions: The Ecosystem Approach and Systems Thinking*. Nairobi: UNEP. Available at www.unep.org/resources/toolkits-manuals-and-guides/wicked-problems-dynamic-solutions-ecosystem-approach-and
4. United Nations Environment Programme (2017). *A Framework for Freshwater Ecosystem Management*. Nairobi: UNEP.

Module 3: Data for decision-making

A. Goal

This module aims to provide participants with an understanding of how data contributes to decision-making, focusing in particular on data sources and on practical tools available for the protection and restoration of freshwater ecosystems.

Learning objectives:

At the end of this module, participants are expected to:

- Understand how data, knowledge and information management supports decision-making for the protection and restoration of freshwater ecosystems
- Have an overview of the range of data sources available
- Learn about specific data tools and techniques, in particular remote sensing, GIS, big data, ecological assessment tools, and reporting and visualization tools
- Learn about the key global online data platforms available
- Gain a contextual understanding through examples of data sets/platforms available in country and their use

B. Introduction: Importance of data

Previous modules alluded to the complexities and dynamism of freshwater ecosystems and the challenges they pose in relation to effective management and/or restoration. Practitioners, stakeholders and decision makers must jointly identify key issues, their drivers and levers of change, and agree on shared objectives for the protection and restoration of freshwater ecosystems and on the means to attain them. This approach must be informed by data, therefore ensuring a good understanding of the situation, supporting fair dialogues between stakeholders and across sectors, thus allowing for the identification of critical areas and potential trade-offs. Evidence-based decision-making should be a priority, as it aids in removing bias and supports informed dialogue and decision-making. In many cases, however, availability of data is a notable constraint.

Great strides have been made over the past 20 years as technological advancements have significantly improved data collection and analytics (e.g. remote sensing, geographic information systems (GIS), R-Stat, SAGA and ILWIS). In addition, increased attention at the policy level to freshwater ecosystems and data to support their management have also helped – on a global scale. For example, the Convention on Biological Diversity, the Ramsar Convention, the Aichi Biodiversity Targets, the Sustainable Development Goals (SDGs), the United Nations Environment Assembly Draft Resolution on addressing water pollution to protect and restore water-related ecosystems and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, all speak to the importance of freshwater ecosystem data. These conventions, policy instruments and initiatives have resulted in comprehensive scientific efforts to generate data and build monitoring and assessment tools (Schmidt-Kloiber et al., 2019).

It is also important to note that data-driven decision-making requires a broader information management approach. Such an approach should include in particular:

- Identifying what the priority information needs are as well as where and how to access the required data
- Data collection, management and analysis
- Communication and sharing of data and knowledge
- Stakeholder involvement at all stages

This module will focus on providing an overview of data types, data collection tools and techniques, data sources and key online data platforms available. The module will also provide some insight as to how data can be used to inform and improve decision-making.

C. Framing data, information and knowledge terminology

As emphasized in the introduction, the practitioner must put in place a good information management approach, to ensure that appropriate information is made available, in a way that supports stakeholders and cross-sectoral dialogues and informed decision-making. In this regard, distinctions must be made between data, information and knowledge. For example, a water quality measure has no specific meaning on its own. Thus, this data must be combined with additional data points, both spatially and temporally, processed and interpreted prior to being contextually applied and informing decision-making.

While the terminologies of knowledge, information and data may sound similar, and may often be used interchangeably, it is important to note that they are inherently different. As such, we provide here definitions to help practitioners in dealing with the many data tools and techniques. It is good to also note that many different definitions exist around data, information and knowledge, and as such they have varied meanings. However, we present here relatively common meanings that can help the practitioners determine how to make best use of them.

Data is defined as recorded (captured and stored) symbols and signal readings. These symbols can include words (text or verbal), numbers, diagrams and images and are often regarded as the building blocks of communication. Data is the storage of intrinsic meaning and a mere representation. It can also be expressed as an individual unit containing raw unprocessed material which does not uphold any specific meaning. The purpose of data is really to record situations or activities in an attempt to capture a real event (Liew, 2007). Additionally, the data must become organized in order to become information, as it is only an element of analysis. Conversely, information speaks to a message that contains a relevant meaning, implication or input for decision-making and action, and it can be upheld by both contemporary communication and historically processed data. Its main purpose is to guide decision-making, resolve problems and realize opportunity (Liew, 2007). Information, however, must be given context to become knowledge. To this end, knowledge is defined as the following:

> Recognition or cognition, commonly known as the "know-what", the inherent capacity to act, commonly known as the "know-how", and understanding, commonly known as the "know-why" (Liew, 2007).

To that end, the main purpose of knowledge is to cultivate and increase the value for the enterprise and its attendant stakeholders, as knowledge is really centred on value creation (Liew, 2007).

D. Data types, sources and collection types

1. Data types

Data can be divided into two main types: quantitative and qualitative. Quantitative data deals with numbers, and things that can be objectively measured (e.g. water quality measurements, temperature, humidity). Qualitative data deals with characteristics and descriptors that cannot be easily measured, but can be observed subjectively (e.g. ecosystem health indicators).

Data sources may be primary or secondary. Primary data refers to data collected directly by an actor for a specific purpose, whereas secondary data refers to data that was previously collected for a different purpose and the information has been stored on record for use by others. Journal articles, national reports and project reports are all forms of secondary data. Practitioners can utilize secondary data in areas of interest to inform the decision-making process and may also carry out their own data collection.

2. Data collection tools

The tools and techniques used to collect data are largely dependent on the information needs and resources available. A list of basic data collection tools includes:

- Interviews: can be carried out in groups or on an individual basis and administered informally or formally. Interviews can be done remotely or face-to-face and can be structured, semi-structured and/or open-ended.
- Surveys and questionnaires: designed to collect information from many groups or organizations.
- Focus group discussions: these occur within small groups of people, who all have a collective specialist knowledge or particular interest in a particular topic. It allows the perceptions and attitudes of that defined group of people to be discerned.
- Observations: a simple method where viewing of objects, processes and relationships occur. There are two types of observations:
  - structured or direct observations which includes the recording of observations against an agreed checklist

    - expert observation which is usually carried out by someone with specific expertise in a particular area of work
- Direct measurement: changes are monitored through on-site sampling and measurements. This also includes geospatial data via remote sensing and aerial photography.
- Review of secondary data sources: such as government statistics, global or regional online data platforms, NGO reports, newspapers, website articles, research studies and evaluations.

Different data collection methods are usually used in combination. For example, if we are attempting to determine the change in water quality over time in a specific river basin, on-site measurements when combined with surveys and focus group discussions that incorporate local knowledge and multi-stakeholder perspectives can serve as an excellent starting point. In many cases, initiatives related to the protection and restoration of freshwater ecosystems will rely primarily on secondary data sources and data collected through surveys and interviews rather than additional direct measures due to limitations in resources available. To that end, box 3.1 lists examples of secondary data sources that can be readily available and at low cost, which can provide the backbone for the development of a freshwater ecosystem action plan.

Box 3.1. Examples of secondary data sources that can be mobilized for a freshwater ecosystem situation analysis

- Country or basin information systems, especially on water resources and on ecosystems.
- SDG 6.6.1 Explorer Platform and complementary online data portals.
- Key informant interviews.
- Reports, publications and databases available at the regional, national or subnational levels that include/highlight the status of freshwater ecosystems, pressures, drivers and trends.

3. Focus on specific data tools and techniques

Here, we focus particularly on specific data tools and techniques that make particular use of digital technologies, and that the practitioner may find useful in their work.

(a) Literature analysis tools

There is a vast amount of literature available in a digital format on various topics related to freshwater ecosystems management and restoration. Practitioners can utilize text analysis tools to automatically extract information from digital text, such as identifying common themes, areas of focus and so on. Some can be used via an online interface; others can be installed locally on a desktop/laptop. Some general examples of these tools are provided in box 3.2.

Box 3.2: Literature/text analysis tools

Concordance tools
Tools of this nature search for a word or phrase and see all instances in your text, displayed with a limited amount of context:

- **Antconc:** www.antlab.sci.waseda.ac.jp/ – a tool that you install locally and use to explore texts in various ways, for example by creating concordances, word lists and collocations.
- **LexTutor:** www.lextutor.ca/
- – a set of tools that you can use on pre-loaded texts or material that you add. Includes a concordance program, word list functions and much more.
- **Taporware:** www.tapor.ca/ – a wide range of specialist text analysis tools.

Voyant Tools
These are embedded in a web-based text reading and analysis environment. It is a scholarly project that is designed to facilitate reading and interpretive practices for digital humanities students and scholars as well as for the general public (https://voyant-tools.org/).

Word class taggers
These are tools that will analyse the words in your text and mark this part of speech. These are two taggers available for free online:

- **CLAWS online tagger:** http://ucrel.lancs.ac.uk/claws/trial.html
- **Wmatrix:** http://ucrel.lancs.ac.uk/wmatrix/

(b) Remote sensing techniques

Remote sensing plays an increasingly important role in freshwater ecosystems management. Such a technique contributes to the development of objective and comprehensive assessments over larger geographic extents than is possible with fieldwork alone. Remote sensing facilitates objective, repeatable analyses that can help detect and monitor change over time.

Remote sensing is a method of observing the Earth's surface without being directly in contact with it and includes different tools; this is most commonly through airborne sensors installed on fixed-wing planes or helicopters or via satellite sensors orbiting the Earth. Airborne sensors are typically used to collect data on demand on relatively small areas. Remote sensing satellite systems are increasingly developed, and more and more platforms provide freely available data based on such satellite systems (see "Global platforms" section, below).

ES, ESP, or ecological process	RS products	Source
Plant traits	Pigment, dry matter, water, chemistry content, LAI, LAD Roughness, height, vertical structure. Life form Phenology	Spectral analysis or radiative transfer models LiDAR, RADAR, multiangle RS Land cover classification Multitemporal RS
Species	Species map Habitat suitability map	Chemical or structural uniqueness, HSI, LiDAR, image texture Varied, e.g. climate, topography, land cover, productivity
Biodiversity	Spectral diversity Environmental surrogates	Range or variability of biochemistry, NDVI, or reflectance in set of pixels Varied, e.g. productivity, topography, land cover, disturbance
Abundance of functional components	Vegetation fraction, litter fraction	Spectral unmixing, MODIS Continuous Fields
Biomass, C storage	Canopy structure	LiDAR, RADAR, multiangle RS
Photosynthesis, C sequestration	Productivity	fPAR, photosynthetic efficiency, fluorescence, MODIS NPP
Disturbance	Change in biomass, plant traits, land cover Fire detection Drought monitoring Plant stress	Multitemporal RS Thermal anomalies Water content, surface temperature, ET Spectral indexes
Soil characteristics	Land form Soil texture, moisture, chemistry	DEM RADAR, HSI
Evapotranspiration	Evapotranspiration	Thermal remote sensing, VIs, climate data
Hydrology variables	Precipitation Soil moisture Water, snow/ice extent Water level Ground water	RADAR, passive microwave RADAR Optical, RADAR, passive microwave RADAR altimetry Gravity surveys, subsidence, surface water fluxes
Landscape structure	Landscape metrics	Land cover, quantitative heterogeneity patterns
Ecosystem classification	Ecosystem classification	Varied, e.g. productivity, climate, topography, land cover

Table 3.1: Capabilities of remote sensing to provide useful information to contribute to freshwater ecosystem assessments. Source: Andrew et al. (2014).

Two useful references to learn more about remote sensing are:

- The Convention on Biological Diversity Technical Series No. 32, which provides useful guidance and examples on the application of remote sensing to biodiversity monitoring and environmental management (www.cbd.int/ts32/).
- The Ramsar Convention Technical Report No. 10. 2018: The use of Earth Observation for Wetland Inventory, Assessment and Monitoring, which presents approaches that aid in ensuring the wise use and conservation of wetlands at national and global scales (Rebelo et al., 2018) (www.ramsar.org/document/ramsar-technical-report-10-the-use-of-earth-observation-for-wetland-inventory-assessment).

(c) Geospatial analysis and geographic information system

GIS can be defined as a "computer-based system" to aid in the collection, maintenance, storage, analysis, output and distribution of spatial data and information. GIS and spatial analyses are particularly concerned with the quantitative location of notable features, as well as the properties and attributes of those features (Bolstad, 2017). Some commonly used GIS tools include the following:

- Overlay and proximity
- Spatial and nonspatial statistics
- Table management, selection and extraction
- Kriging and inverse distance weighted interpolation (IDW) are also common methods used when dealing with freshwater ecosystems

GIS can also be used to develop spatial models and simulations, which is an analytical process that aids in describing the basic processes and properties for a given set of spatial features. These techniques are limited by the availability of baseline data sets, as many countries lack data for the input parameters necessary to effectively utilize contemporary models. Fortunately, open access platforms with spatial data (see "Global platforms", below) are now increasingly available along with free software for processing and analysis (e.g. QGIS, ILLWIS, R and R Studio).

Examples of GIS applications for investigating inland waters and integrating biological and physical assessments:

1. Watershed delineation and river channel identification within a GIS environment can help determine and assess river ecosystems. This can be achieved through watershed classification, hillslope derived sediment modelling and relating watershed characteristics with biota (Gardiner, 2002). Additional data that can be used are other watershed and river attributes such as forest cover, land use, discharge at specific points, species and other infrastructural features that affect hydrology and biodiversity of freshwater ecosystems. GIS can then be used to analyse the physical and biological attributes, trends and patterns of various freshwater ecosystems. Further analysis can involve digital elevation models in conjunction with remote sensing to determine the direction of flow of water at any point in a landscape. Another approach to freshwater ecosystems modelling is using spatial data

that delineates watersheds, classifies attributes and investigates morphometry to evaluate sedimentation of freshwater ecosystems. This evaluation is important to assessing the influence of land-use decisions on freshwater ecosystems. The SDG 6.6.1 Explorer platform is a good example of how trends can be tracked and spatially represented. This will be discussed in detail in module 4.

2. Another GIS approach can be to utilize multimetric indicators. Multimetric indicators statistically describe species in a specific location and its surrounding environment relative to undisturbed sites that display similar characteristics (Gardiner, 2002). Multimetric indicators can be used to investigate properties of freshwater ecosystems to determine the likely causes of degradation and management decisions that can be implemented (Schoolmaster et al., 2012). Multimetric scores are given based on characteristics of a region and expertise consultations with ecologists, which are then compared to land-use data acquired from remote sensing and extracted on a watershed basis using GIS. Established from this is a statistical description of the effects of watershed practices on the biodiversity of freshwater ecosystems. This multimetric approach can be used for a meaningful prediction of the integrity of the freshwater ecosystems. For this to be done, a multimetric index (MMI) which is generated from a boosted regression tree approach can be applied. The MMI will be indicative of a predictive model of the national data sets used. For an example of the method see the approach taken by Clapcott et al. (2014).
3. Another useful example of the use of GIS in spatial modelling is the Monitoring of Freshwater at High Spatio-temporal Resolutions (http://spatial-ecology.net/projects/).
4. Public participation geographic information systems (PPGIS) is another application that can be used to investigate inland waters and integrate biological and physical assessments. Accordingly, PPGIS pertains to the use of GIS in a way that supports participation and enhances stakeholder involvement in the decision-making process. PPGIS can be conducted, for example, by asking participants to map ecosystem services, in combination with supporting data sets about the respective ecosystem. More information on PPGIS including spatial mapping techniques, technologies, data acquisition methods, spatial analyses and map scales used for mapping of various ecosystems, which can also be applied to freshwater ecosystems, can be found in Brown and Fagerholm (2015).

Contextualization: example of remote sensing and GIS applications in country, relevant for freshwater ecosystems protection and restoration

(d) Big data tools and techniques

Big data offers big opportunities for enhancing environmental management. The term “big data” refers to data that is so large, fast or complex that it is difficult or impossible to process using traditional methods. Big data is characterized by volume (amount of data), velocity (quickly generated) and variety (it can be text, video, data from sensors, etc.). Often, data is unstructured and hence unsearchable (Ratra and Gulia, 2019).

There have been several big data analytics tools developed to aid in the management of big data, a number of which are presented in table 3.2.

	Data collection tools	**Data storage tools and frameworks**	**Data filtering and extraction tools**	**Data cleaning and validation tools**
1	Semantria	Apache HBase (Hadoop database)	Scraper	DataCleaner
2	Opinion Crawl	CouchDB	OctoParse	MapReduce
3	OpenText	MangoDB	ParseHub	Rapidminer
4	Trackur	Apache spark	Mozenda	OpenRefine
5	SAS Sentiment Analysis	Oracle, NoSQL Database	Content Grabber	Talend

Table 3.2: Examples of big data analytics tools. Source: Ratra and Gulia (2019).

Some commonly used big data analytical tools are: Semantria, Opinion Crawl, OpenText and Trackur. Semantria is very useful in finding trends and identifying the varying patterns, as it is a tool that powerfully combines various text analytics (Ratra and Gulia, 2019).

Apache Hadoop is one of the major technologies designed to process big data, which is the unification of structured and unstructured huge data volumes. The Apache Hadoop technology is an open access/source platform and processing framework which provides batch processing. Traditional statistical software such as MINITAB and SPSS are also very useful in analysing data; however, these are not open source, thereby limiting use.

(e) Integrating diverse multi-scale data

Freshwater ecosystem characteristics are challenging to map and spatially monitor. Apart from the dynamic nature of the ecosystem features, resolution and scale of available data can complicate representation and modelling.

Data integration is the practice of consolidating data from disparate sources into a single data set, with the ultimate goal of providing users with consistent access, and delivery of data to meet the needs of all applications (Samuelsen et al., 2019).

National and local data originates from various sources, can be stored in different formats and has varying levels of structure. Data integration facilitates management of the large amounts of data from diverse sources into a single framework (Sivarajah et al., 2017). This approach helps countries cohesively access the data and use the information to monitor, plan and implement appropriate strategies to sustainably protect and manage their freshwater ecosystems (Chatti et al., 2017).

Data integration is not without challenges:

- Data inconsistencies can occur during the analysis and integration of data from different sources, where each data set may represent the same information in a different way. This results in redundancy and inefficiency of the data capture methods and it is time-consuming to reconcile these issues (Bansal and Kagemann, 2015).
- Other types of problems that often appear when integrating data include missing data, improperly entered data or other common “dirty data” problems. Thus, data fusion from heterogeneous sources represents a significant advantage when unifying data, since this serves to obtain an overall view of the geospatial integrated framework (Castanedo, 2013). However, in the data fusion from heterogeneous sources several problems arise during the integration process, such as data association and uncertainty of the sensors due to external environmental factors as well as data administration, among others (Kumar and Garg, 2009). These and other problems in data fusion and integration from varied sources create challenges that need to be addressed.
- Challenges in data fusion arise due to the varied format and type of sources and data imperfection. Figure 3.1 presents the identified challenges, which were classified according to the nature of the data.

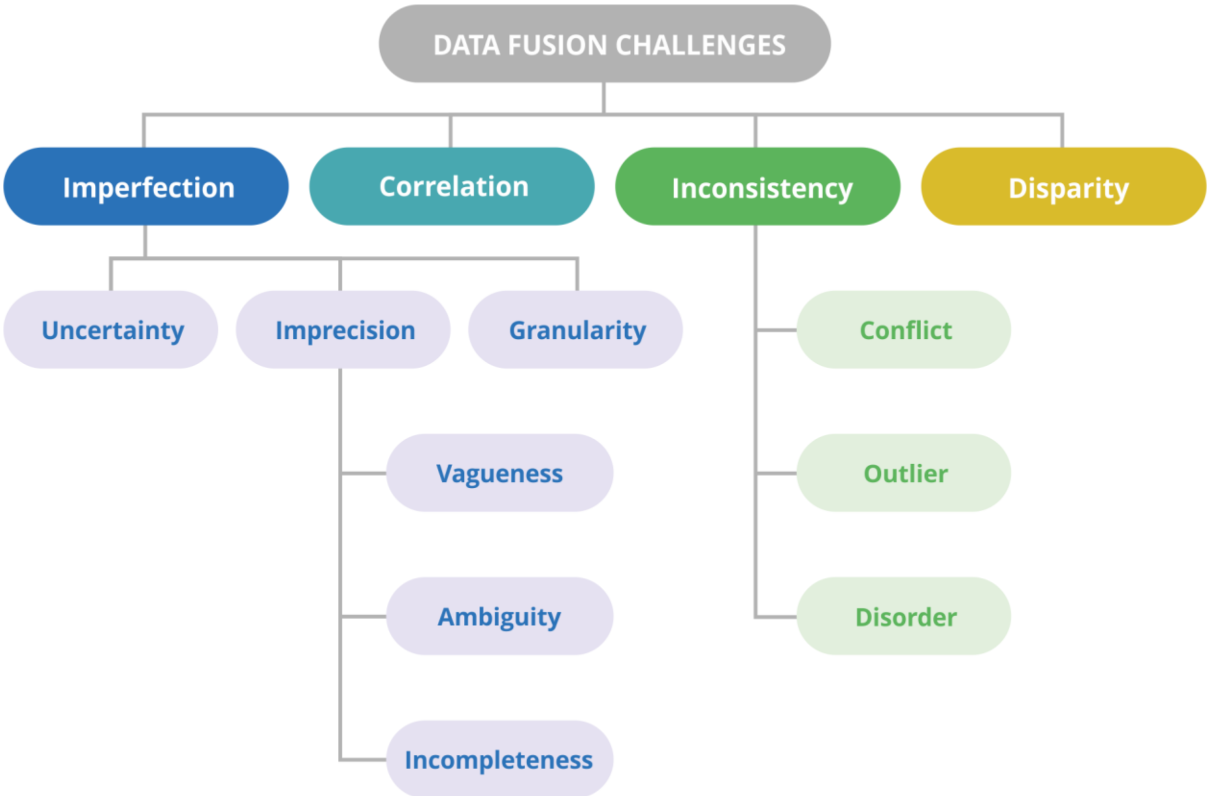

Figure 3.1: Classification of the current challenges in data fusion. Source: adapted from Khaleghi et al. (2013).

Therefore, a fundamental aspect in data fusion is the ability of fusion methods to maintain data consistency, avoiding conflicts, outliers and disorder from diverse sources (Kale and Aparadh, 2016). To extract meaningful, accurate and relevant information from structured and unstructured data consistently, it is expected that a common conceptual model for integrated data should exist (Azzini and Ceravolo, 2013). More specifically, it is expected that data is stored in a consistent format in order to facilitate further analysis. To this extent, data formats must be consistent across all scales.

4. Ecosystems services assessment tools and platforms

Different freshwater ecosystem types, and specific ecosystems among them, provide different ecosystem services. Identifying, measuring, modelling and valuing ecosystem services are important to the protection and restoration of freshwater ecosystems.

As a first approach, key ecosystems services provided might be identified through existing literature, consultations with experts and engagement with stakeholders as mentioned earlier. To go further, an array of ecosystem services assessment tools have been developed in recent years. Some examples of these tools are provided in box 3.3.

For additional information on ecosystem assessment tools see Neugarten et al. (2018).

Box 3.3: Categorization of ecosystem services assessment tools

Written (step-by-step guidance documents):

- Ecosystem Services Toolkit (http://publications.gc.ca/site/eng/9.829253/publication.html)
- Protected Areas Benefits Assessment Tool (https://wwf.panda.org/?174401/PABAT)
- Toolkit for Ecosystem Service Site-based Assessment v.2.0 (http://tessa.tools/)

Computer-based modelling tools:

- Artificial Intelligence for Environment & Sustainability (https://aries.integratedmodelling.org/)
- Co$ting Nature v.3 (www.policysupport.org/costingnature)
- WaterWorld v.2 (www.policysupport.org/waterworld)

5. Analytical hierarchy process

Analytical hierarchy process (AHP) is a decision-making process that collates quantitative and qualitative analysis using a matrix. The process comprises four main steps: (i) problem modelling and making hierarchical structure, (ii) evaluating weights, (iii) combining weights, and (iv) analysing sensitivity. Figure 3.2 displays, for example, a flow chart for an ecological vulnerability assessment of wetlands. Also, figure 3.3 shows an example of a potential output map using AHP and GIS (in this case assessing the groundwater potential in an area).

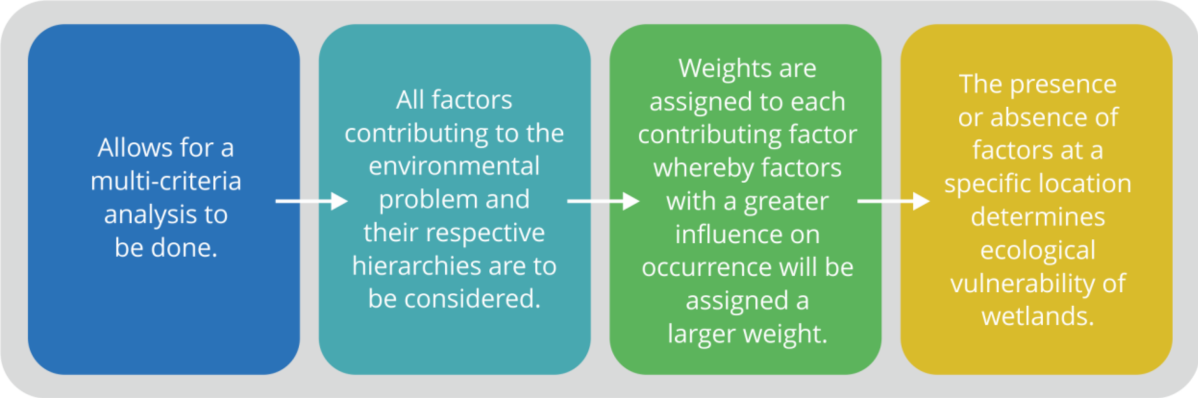

Figure 3.2: Main steps to be undertaken for AHP analysis of the ecological vulnerability of wetlands.

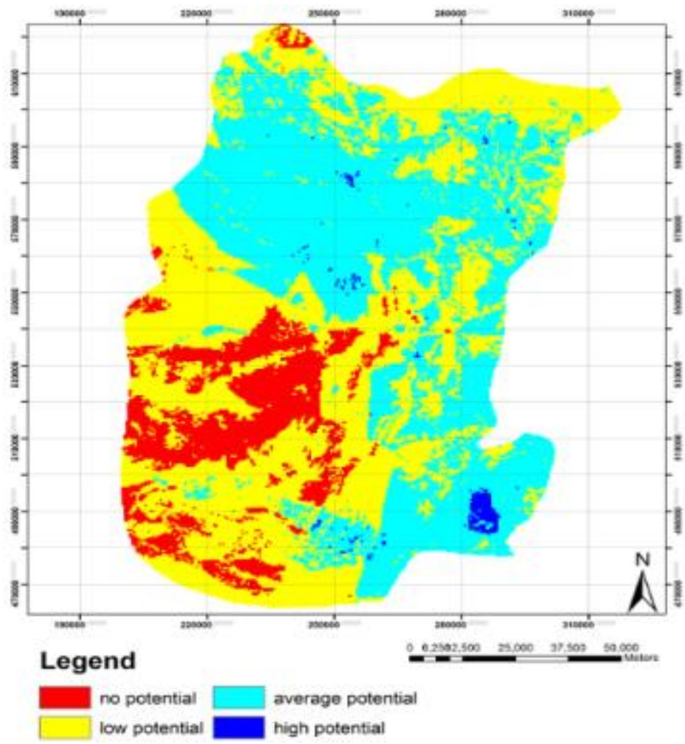

Figure 3.3: Example of groundwater potential output map derived from AHP. Source: Zeinolabedini and Esmaeily (2015).

6. Reporting and visualization tools

The way data is presented plays a crucial role in its uptake, relevance and digestibility for stakeholders and decision makers. This is particularly true for complex environmental systems such as freshwater ecosystems. Data must, therefore, be strategically represented to allow stakeholders and decision makers to see clear trends and identify critical areas of focus when managing freshwater ecosystems.

The main uses of data visualization are:

- Improved decision-making
- Information sharing
- Time saving (limits the need for end user assessments)

Generally speaking, some common data visualization tools include charts, tables, graphs, maps, infographics, word cloud charts and dashboards. The choice of data visualization tool is directly related to the type of data to be communicated (i.e. a word cloud would work for a survey, a graph would help visualize quantitative data, etc.). Examples are provided in figures 3.4, 3.5 and 3.6.

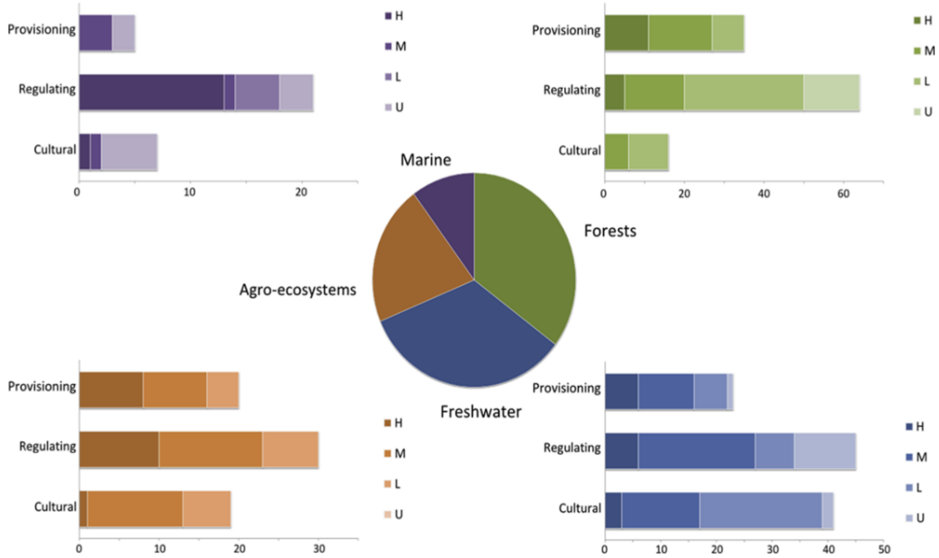

Figure 3.4: Example of graphs for data visualization. Source: Maes et al. (2016).

Figure 3.5: Example of word cloud chart. Source: Colourbox.com.

Figure 3.6: Example of infographic on a freshwater ecosystem. Source: Lake Simcoe Georgian Bay Wetland Collaborative (www.arcgis.com/apps/MapJournal/index.html?appid=cf90acb50243403b885eadcaf134e96a).

7. Global platforms

Contemporary techniques for data gathering and analysis now enable the ability to collect, store, merge, sort and analyse enormous amounts of environmental and geospatial data. These techniques and tools have spurred the development of numerous platforms providing ecosystem and biodiversity data that are readily available to the practitioner.

The range of data available on different platforms includes information on the status of ecosystems, on pressures, drivers and historical trends. Accordingly, we are providing the following examples of such platforms:

- The Global Biodiversity Information Facility (www.gbif.org/what-is-gbif) provides information on, about, where and when species have been recorded for all types of ecosystems, including freshwater ecosystems.
- The Freshwater Information Platform (www.freshwaterplatform.eu/) provides information, research resources and tools for the assessment and management of freshwater ecosystems. It is mostly focused on Europe but also provides broader information. It includes for example data (from information about data sets (metadata) to occurrence and species data from Europe and beyond), as well as visualizations, geographic data and thematic maps related to biodiversity, freshwater resources and pressures. Schmidt-Kloiber et al. (2019) provide a comprehensive overview of the

platform's core components, highlighting their values, and presenting options for their use and future development.

- UNdata (https://data.un.org/) brings together UN statistical databases.
- FAOSTAT (www.fao.org/faostat/en/#data) is the global statistical database of the United Nations Food and Agriculture Organization. It provides free access to food and agriculture data some of which can be applicable to freshwater ecosystems.
- Google Earth Engine (https://earthengine.google.com/) enables users to visualize and analyse satellite images of the planet. A recent development, Earth Engine's Timelapse shows, for example, land coverage changes across 32 years, and can help to show some environmental trends, for example, the reduction in size of some freshwater ecosystems.
- USGS Landsat (www.usgs.gov/core-science-systems/nli/landsat) provides satellite imagery dating back to 1972 and can be accessed through the EarthExplorer website.
- Copernicus (www.copernicus.eu/en) is the European Union's Earth Observation Programme. It draws from satellite Earth observation and in situ (non-space) data. Copernicus services process and analyse the data to provide ready to use information to users. For example, the Copernicus Land Monitoring Service provides geospatial information on land cover and its changes, land use, vegetation state, water cycle, cryosphere and Earth surface energy.
- HydroSHEDS (www.hydrosheds.org/) is a mapping product that consists of hydrographic data on a near global basis at multiple resolutions. This database can be used in conjunction with other open-source websites to guide watershed analysis, hydrological modelling and freshwater conservation planning to address the lack of high-resolution data. A report investigating freshwater habitats using sub-pixel classification further explains how remote sensing can be utilized for mapping different freshwater habitat zones (Ashraf et al., 2007).
- SDG 6.6.1 Freshwater Ecosystems Explorer platform (www.sdg661.app/), which will be presented in module 4.

Contextualization: extracts from some of the global platforms with data and information relevant to the country

E. Decision-making under uncertainty and complexity: use of data

Freshwater ecosystems are dynamic and complex systems. Change is inevitable, and this variability poses fundamental challenges for assessment, design of appropriate responses and monitoring (Clarke and Hering, 2006). Variation occurs in time and space, on both small and large scales. They may be chemical and biological changes in response to hydroclimatic variations, or changes in habitats linked to land-use evolutions driven by socioeconomic developments.

Knowledge of freshwater ecosystems is inherently marked by uncertainties, whether these relate to uncertainties in measurement, insufficiency of data or difficulties in assessing the complex linkages between the state of the ecosystems, the pressures and drivers of pressures, and trends.

It is important that practitioners, stakeholders and decision makers recognize the uncertainty and complexity in the approaches they develop regarding freshwater ecosystems.

Dealing with uncertainty and complexity

Estimating, communicating and managing uncertainty and complexity remains a major challenge for environmental management. Data and the way data is used in stakeholder engagement and decision-making processes have an important role to play in this regard.

A first level of response relates to taking steps to reduce uncertainty. For example, data collection on ecosystems is subject to limitations, owing to inevitable natural variation, limitations in measurement capacity and varying sampling procedures. At this level, three steps can minimize uncertainty:

- Ensure sample replicates – A single sample provides a snapshot of information but does not allow for determination of trends or distribution of site conditions. Randomized sampling can also assist in limiting bias.
- Temporal and spatial considerations – Replicates should not be limited to one location and consideration must be given to seasonal variations. Typically, trend analysis of long-term time series is a good technique to use.
- Ensure statistical rigour – Perform statistical analysis to determine variance and significance.

A second level of response relates to identifying and explicitly recognizing uncertainty. For example, data gaps and uncertainties should be recognized. Presentations of results from models should be accompanied with a presentation of confidence intervals and discussions with stakeholders on the granularity and confidence of the results.

A third level of response rests in the approach to environmental management itself: striving to identify risks, recognize uncertainty, adopt an adaptative management approach and apply the precautionary principle.

To that end, the precautionary principle states that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically (Kriebel et al., 2001). This principle gained prominence because of the perceived disparity between the rate of environmental degradation and society's ability to identify and correct it. The precautionary principle is of particular importance in situations where socioeconomic priorities and/or weak enforcement of regulations may compromise protecting the environment and attendant public health. The principle can inform decisions under uncertainty, highlight the importance for research and innovation and help build public confidence. Some key guiding principles in adopting the precautionary approach are identified by Harremoës et al. (2002) and highlighted in box 3.4.

Box 3.4: Main guiding principles in adopting a precautionary approach

- Acknowledging and responding to ignorance, uncertainty and risk.
- Ensuring that real world conditions are adequately accounted for in regulatory appraisal.
- Ensuring the use of "lay" and local knowledge, as well as relevant specialist expertise, and taking full account of the assumptions and values of different social groups.
- Maintaining the regulatory independence of interested parties while retaining an inclusive approach to information and opinion gathering.
- Identifying and reducing institutional obstacles to learning and action.
- Avoiding "paralysis by analysis" by acting to reduce potential harm when there are reasonable grounds for concern.

Source: Harremoës et al. (2002).

F. Conclusion

Knowledge on data collection, representation and analytical techniques is critical for action to protect and restore freshwater ecosystems. Ultimately the data used and the manner in which it is used depend on the specific purpose and are at times limited by the local circumstances and technical capacity of practitioners. Practitioners must therefore examine all available options and choose accordingly. Efforts must also be placed on transforming data to increase its relatability to non-experts and policymakers to ensure that the message is effectively conveyed.

Recommended reading

1. *Convention on Biological Diversity Technical Series No. 32: Sourcebook on Remote Sensing and Biodiversity Indicators*.
    - Chapter 1: Introduction. Available at www.cbd.int/ts32/ts32-chap-1.shtml
    - Chapter 3: The basics of remote sensing. Available at www.cbd.int/ts32/ts32-chap-3.shtml
2. Rebelo, L.-M., and others. *The Use of Earth Observation for Wetland Inventory, Assessment and Monitoring: An Information Source for the Ramsar Convention on Wetlands. Ramsar Technical Report No. 10*. Gland, Switzerland: Ramsar Convention Secretariat, 2018.
    - Summary, pages 4 and 5. Available at http://www.ramsar.org/document/ramsar-technical-report-10-the-use-of-earth-observation-for-wetland-inventory-assessment
3. Bolstad, Paul. *GIS Fundamentals – A First Text on Geographic Information Systems*, 5th edition, 2016.
    - Chapter 1. Available at http://ratt.ced.berkeley.edu/readings/read_online/Bolstad/Chapter1_5th_small.pdf
4. Neugarten, R.A., and others. *Tools for Measuring, Modelling, and Valuing Ecosystem Services*. Gland, Switzerland: IUCN, 2018.

- Executive summary and Introduction. Available at https://portals.iucn.org/library/sites/library/files/documents/PAG-028-En.pdf

Recommended videos

1. For further in-depth knowledge of remote sensing techniques: NASA ARSET: Introduction to SDG 6.6 and Remote Sensing Techniques for Mangroves, 2020.
   - Part 1: www.youtube.com/watch?v=eFn00Q77HDY&t=796s
   - Part 2: www.youtube.com/watch?v=5Venmt7t6BI

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Module 4: SDG 6.6.1 Explorer platform

A. Goal

This module aims to demonstrate the use of the global data platform (SDG 6.6.1 Freshwater Ecosystems Explorer platform), depicting its accuracy, the high-resolution geospatial data and the up-to-date support given to countries.

Learning objectives:

At the end of this module, trainees are expected to:

- Gain an understanding of the SDG 6.6.1 Explorer platform
- Obtain a contextual understanding through examples of using national data from the SDG 6.6.1 Explorer platform

B. Introduction: What is the SDG 6.6.1 Explorer platform?

The Freshwater Ecosystems Explorer platform (www.sdg661.app/) is an open access, free and easily understandable data platform, provided by the custodian agency, the United Nations Environment Programme (UNEP), as seen in figure 4.1. It provides the user with accurate, up-to-date and high-resolution geospatial data, depicting the spatial extent to which freshwater ecosystems are changing over time, globally and at various scales. The platform allows users to download and visualize spatial data at the national, subnational, basin and sub-basin levels, respectively, for the following ecosystems and water parameters:

- Permanent and seasonal surface waters
- Reservoirs
- Wetlands
- Mangroves
- Water quality (i.e. turbidity and trophic level)

The overarching intention of this platform is to drive evidence-based action towards decisions that would aid in achieving Agenda 2030. This platform became a priority when UNEP in 2017 asked all countries around the world to provide data on their respective freshwater ecosystems. At that time, only around 18 per cent of all countries were able to deliver the requested data, which was very partial, while others simply did not have the data or the capacity to retrieve such data. Hence, UNEP partnered with space agencies, as they were not able to acquire national, in situ data. Major partners include the European Commission’s Joint Research Centre and the Copernicus Space Programme, with the European Space Agency, which provides satellite imagery for the monitoring of ecosystems, and Google for the processing of data and cloud storage. Other partners include National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration

Agency (JAXA). The platform primarily targets the government officials who are responsible for monitoring and reporting data on freshwater ecosystems under the Sustainable Development Goals (SDG) framework but is also open to any interested stakeholders – such as students, academics, scientists and general interested members of the public.

Figure 4.1: Welcome page of the Freshwater Ecosystems Explorer (www.sdg661.app/).

C. Key elements of the Freshwater Ecosystems Explorer

1. Introduction: Gaining access to the Explorer platform

Once users click on "EXPLORE YOUR FRESHWATER ECOSYSTEM", they will be directed to a "United Nations Disclaimer" which highlights the terms of use as seen in figure 4.2.

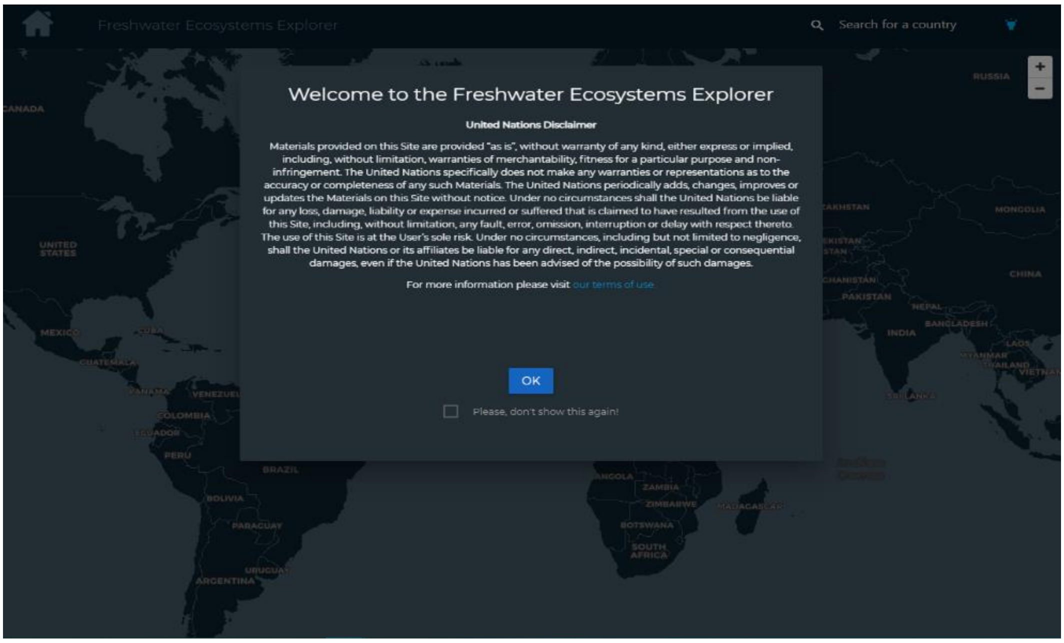

Figure 4.2: "United Nations Disclaimer" page.

Users can then click on a country of interest from the global map presented, which zooms in on that country of interest, displaying a dashboard with country-specific statistics as seen in figure 4.3.

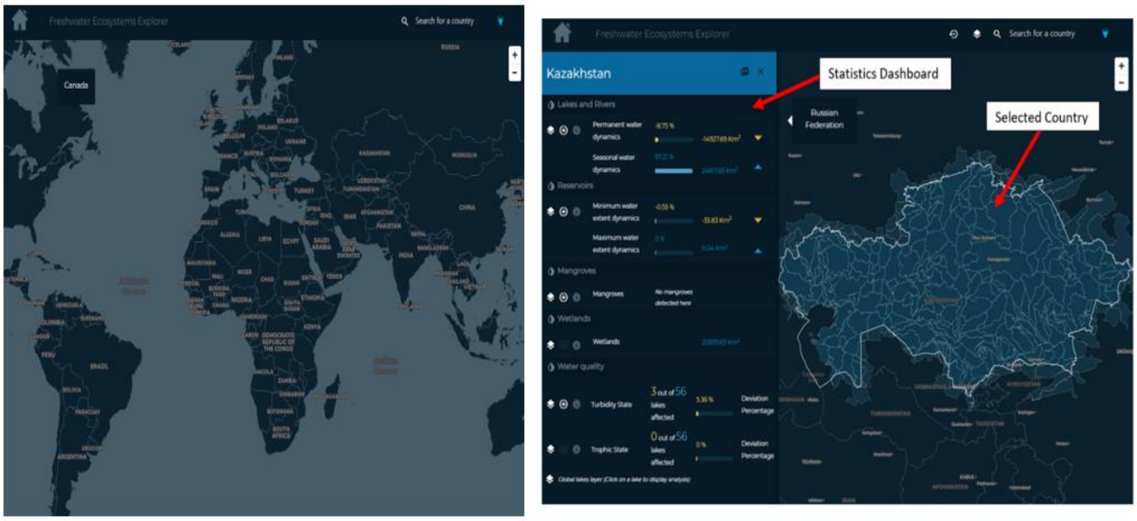

Figure 4.3: General Global Map and country selection panels of the data portal.

2. General characteristics of the data presented in SDG 6.6.1 Explorer platform

1. The statistical information presented represents changes in water-related ecosystems over time. The data is not static but rather dynamic, as this allows determination of long-term trending analysis. Satellite imagery is updated once every year. Data is generated on a rolling average, where a 5-year baseline is generated, and an annual mean is obtained to get the most robust and comprehensive statistical trending analysis.
2. Statistics can be viewed at the national and subnational level as well as the basin and sub-basin level, and they are broken down into different types of freshwater ecosystems as indicated above.
3. Lakes, rivers and reservoirs represent collected data on every open surface waterbody, which is mapped by the satellites that scan the Earth every six to seven days at a 30 m resolution. The data on surface water is separated even further into artificial waterbodies (i.e. reservoirs) and natural waterbodies (i.e. lakes and rivers). NOTE: Rivers that are less than 30 m wide are not included as they are too small.
4. Wetlands are documented as “inland wetlands” and “coastal wetlands”, which are known as “mangroves”.
5. Data is highly ecosystem specific, which allows accurate data to underpin the decisions that ought to be made regarding any particular type of freshwater ecosystem and its conservation and protection.
6. Water quality is presented, but it only refers to very large lakes of resolutions 300 m x 300 m; therefore, the satellite imagery documents on average 4,300 lakes globally.
7. Data is separated into “statistics of change” from a baseline, from the year 2000, as seen in figure 4.4.

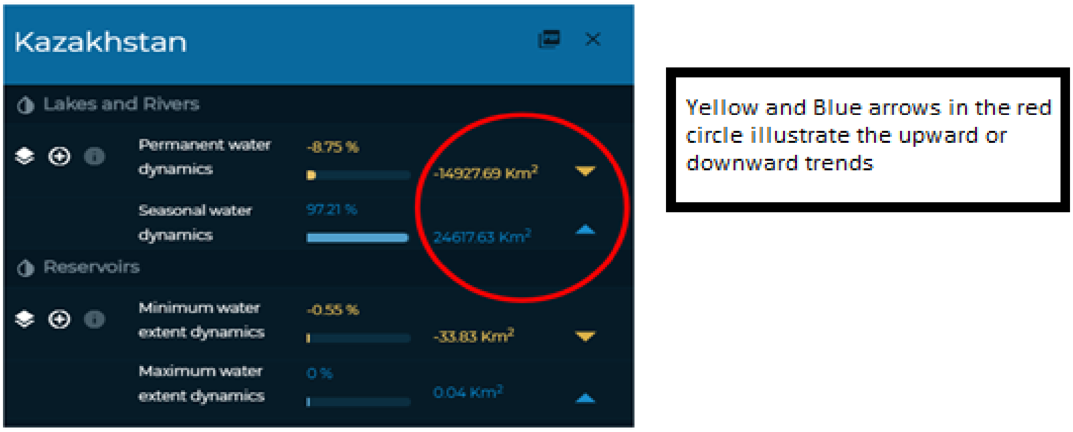

Figure 4.4: Statistics of change for permanent and seasonal water dynamics for lakes and rivers.

8. Water quality is separated into two parameters, (i) turbidity and (ii) trophic state, which can be measured from space. These are proxy indicators and do not represent in situ measurements. Turbidity speaks to the cloudiness of the water, and the trophic state is an indication of eutrophication in the water, which is often driven by nutrient run-off (i.e. nitrogen and phosphorus). The algal blooms are identifiable by the satellite allowing measurement for every 30 m x 30 m square pixel for a large lake for the total amount of lakes.

D. Other functionalities of the SDG 6.6.1 Explorer platform

1. Water transitions

This feature is illustrated by the map icon, which allows the user to see varying water transitions over a particular period. These are categorized as Permanent, New Permanent, Lost Permanent, Seasonal, New Seasonal, Lost Seasonal, Seasonal to Permanent and Permanent to Seasonal, by varying colours as seen in figure 4.5. This feature allows the user to not only see water statistics at the national level, but also zoom into individual basins once they are aware of their location. Such transitions can also be visualized for ecosystem change such as mangroves and wetlands, showing mangrove gain, loss and stability, as seen in figure 4.6. Transitions can also be depicted for trophic and turbidity states, showing average trophic and turbidity states for a year as normal water, low, medium, high and extreme, as seen in figures 4.7 and 4.8.

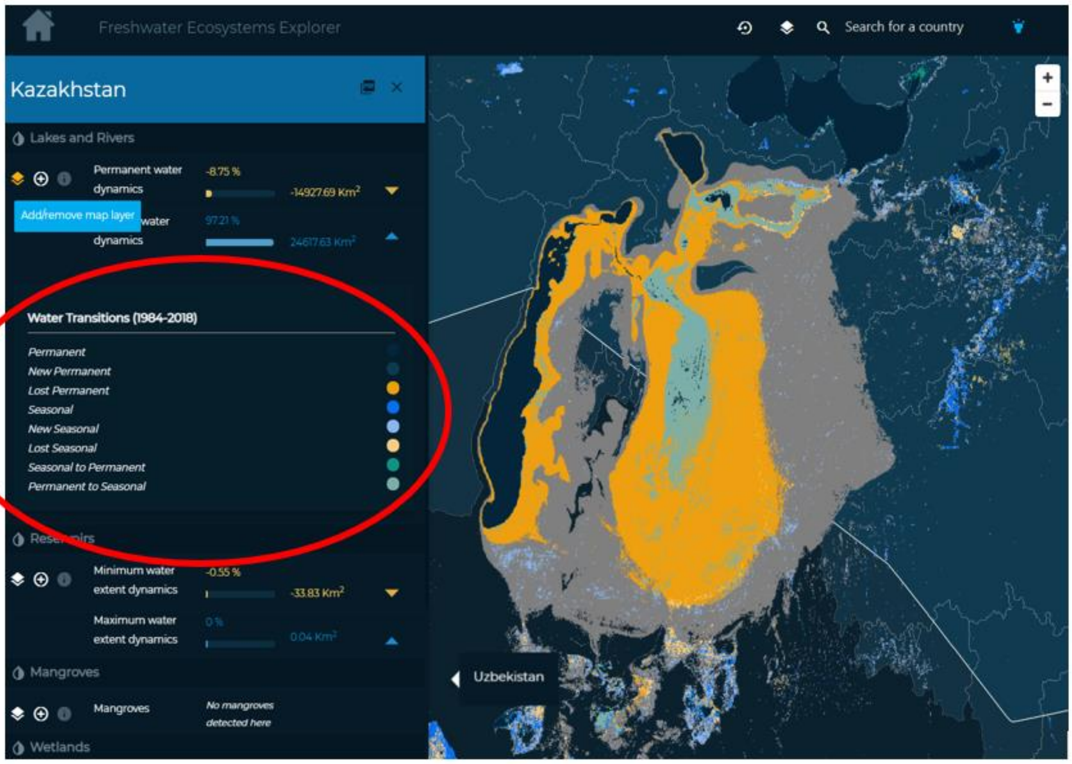

Figure 4.5: Water transitions in Kazakhstan for the period 1984–2018.

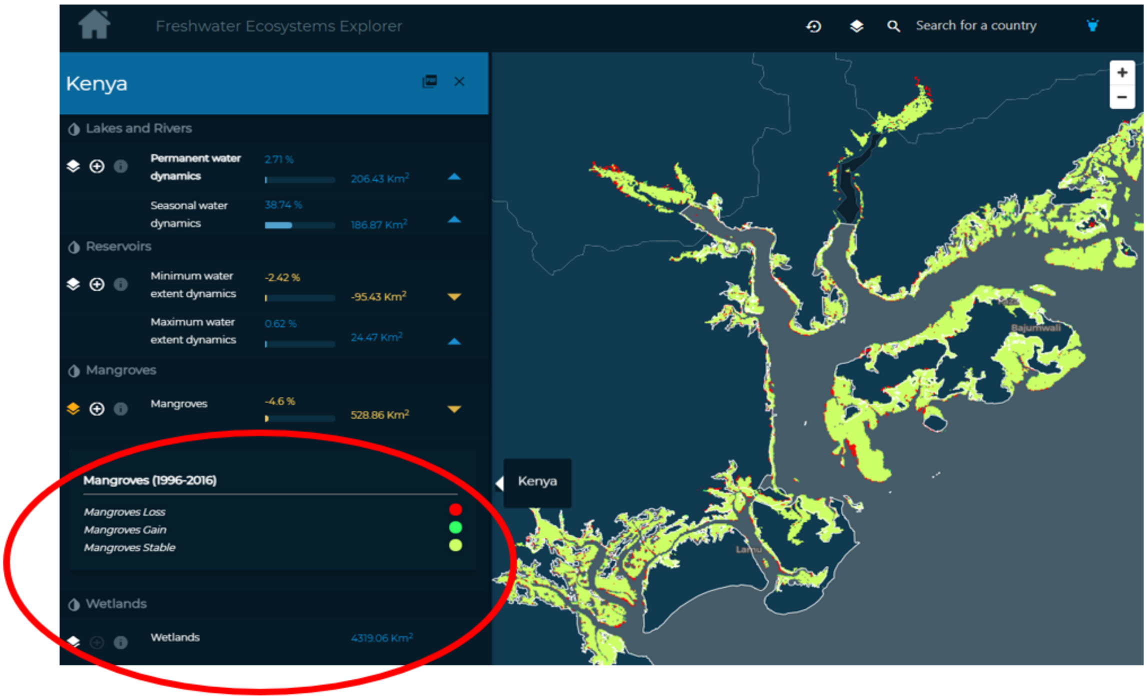

Figure 4.6: Mangrove transition for the period 1996–2016 in Kenya.

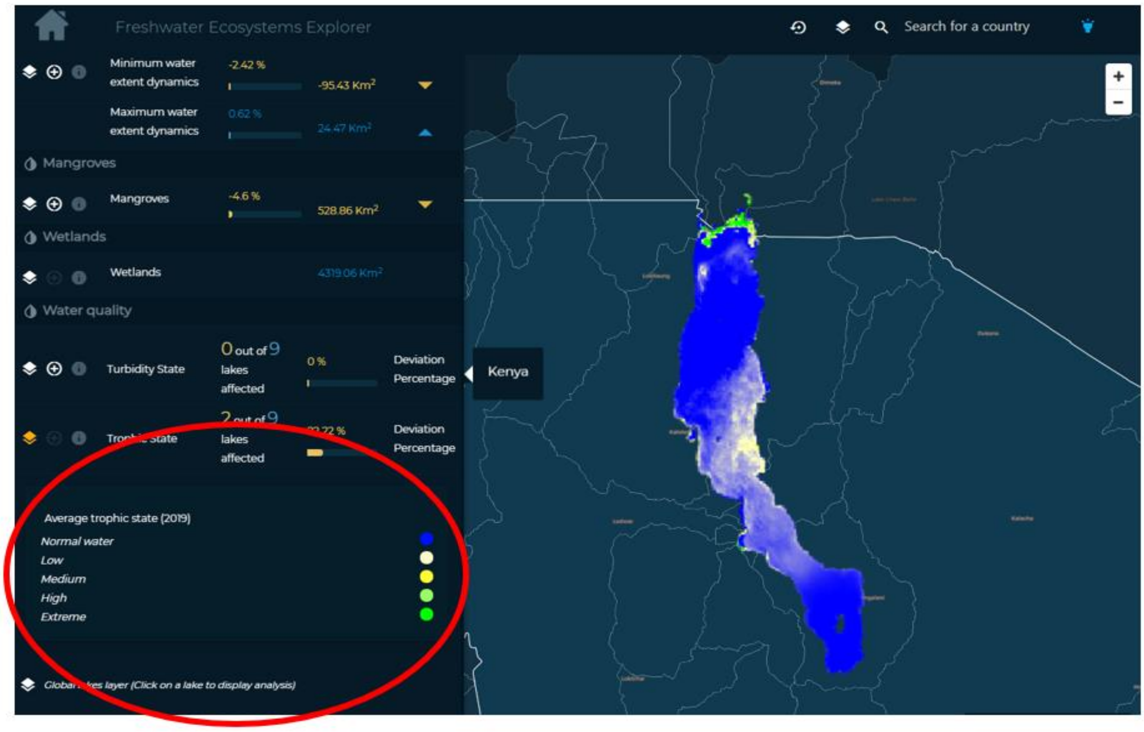

Figure 4.7: Trophic state for Lake Turkana in Kenya (2019).

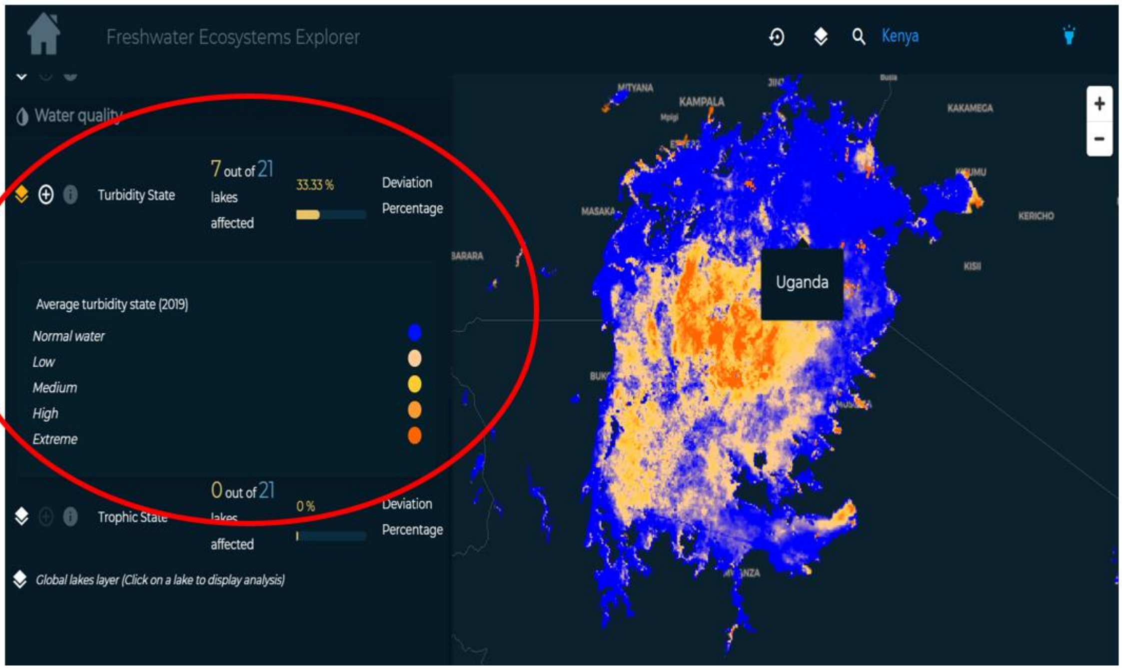

Figure 4.8: Turbidity state for the transboundary Lake Victoria in the states of Kenya, Uganda and the United Republic of Tanzania for 2019.

2. Transboundary statistics

Often natural waterbodies do not follow human-made administrative boundaries. Therefore, for waterbodies that cross national boundaries, the statistic for each country is highlighted, as seen in the case of Lake Victoria, which crosses the boundaries of Kenya, Uganda and the United Republic of Tanzania, as seen in figure 4.9. This is important, as transboundary cooperation is fundamental in the protection and restoration of freshwater ecosystems, allowing one country to see the data of others.

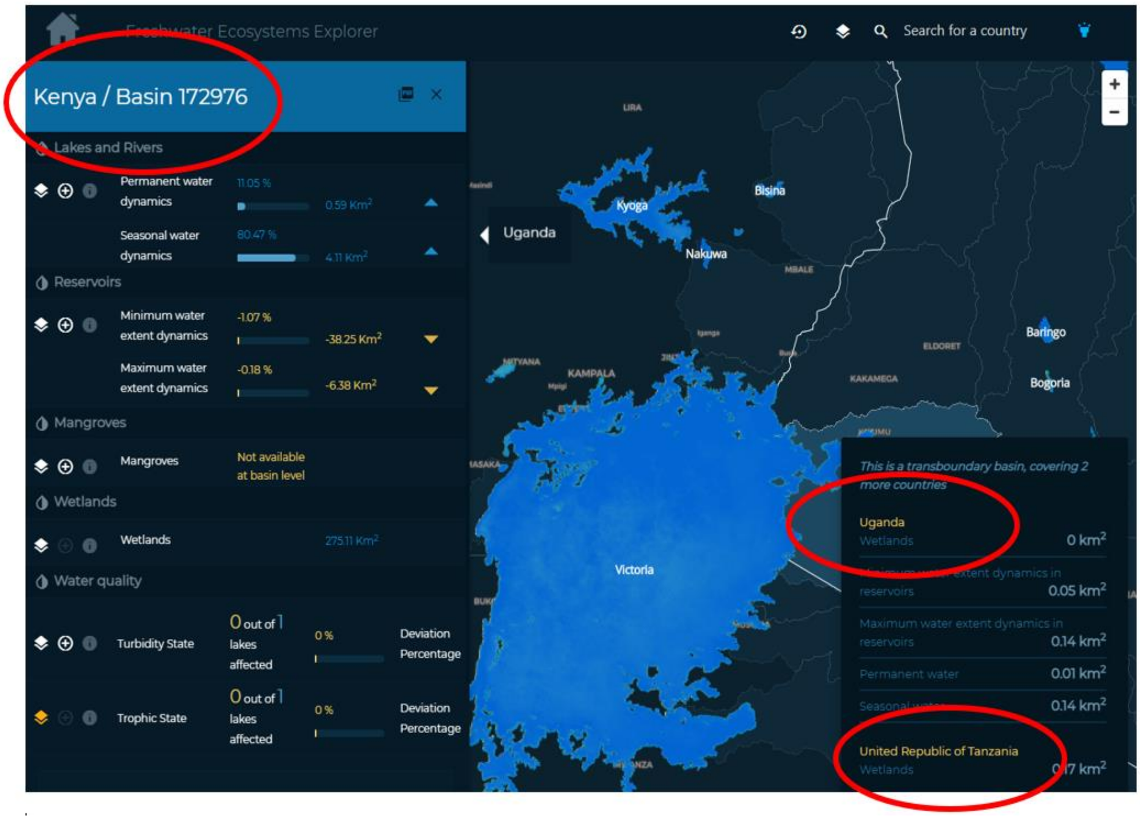

Figure 4.9: Transboundary statistics for Lake Victoria.

3. Hydro basin and admin level statistics

This functionality allows users to view data for a particular basin. It allows the selection of varying scales of basins, going from basin to sub-basin to sub-sub-basin. Regarding administrative scales, there are two admin levels, admin 1 and admin 2, which has a higher resolution, as seen in figure 4.10.

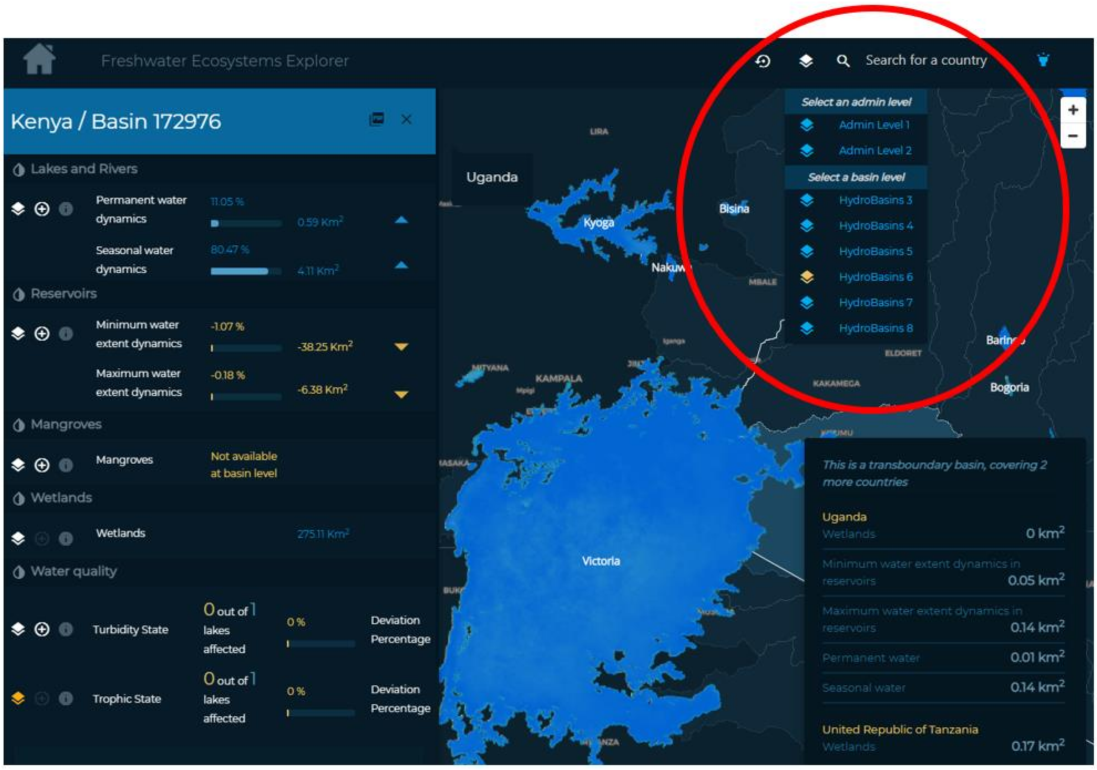

Figure 4.10: Drop-down menu to obtain the admin and basin level options.

4. Advance analysis

Allows users the ability to access higher resolution statistics by clicking on the plus sign (+) on the statistics dashboard. This provides graphs and various charts that show changes over time periods. This advance analysis functionality is available for every data set. This data can be downloaded as graphics in chart/graph form or as the actual numeric and spatial data that underpins the charts presented. The statistical dashboard can also be downloaded by clicking on the pdf icon at the top of the dashboard as seen in figures 4.11 and 4.12.

E. Examples of application of the SDG 6.6.1 Explorer platform

Interesting case stories have been generated by UNEP using the SDG 6.6.1 Explorer platform, which demonstrate changes in different freshwater ecosystems as reported under SDG indicator 6.6.1 but linking these changes to impacts on the ground. These stories highlight the wide array of freshwater ecosystem pressures, the complex interaction between natural and anthropogenic stressors, and how different pressures act over large areas and across long time scales. The stories can be viewed via https://stories.sdg661.app/. This type of analysis and data representation provides an excellent overview of challenges being faced and has the potential to accelerate management and mitigation efforts of freshwater ecosystems.

Examples of stories:

- Water quality (Lake Titicaca): https://stories.sdg661.app/#/story/1/0/0
- Loss of permanent surface water (Australia): https://stories.sdg661.app/#/story/0/1/0
- Mangroves loss (Myanmar): https://stories.sdg661.app/#/story/2/0/0

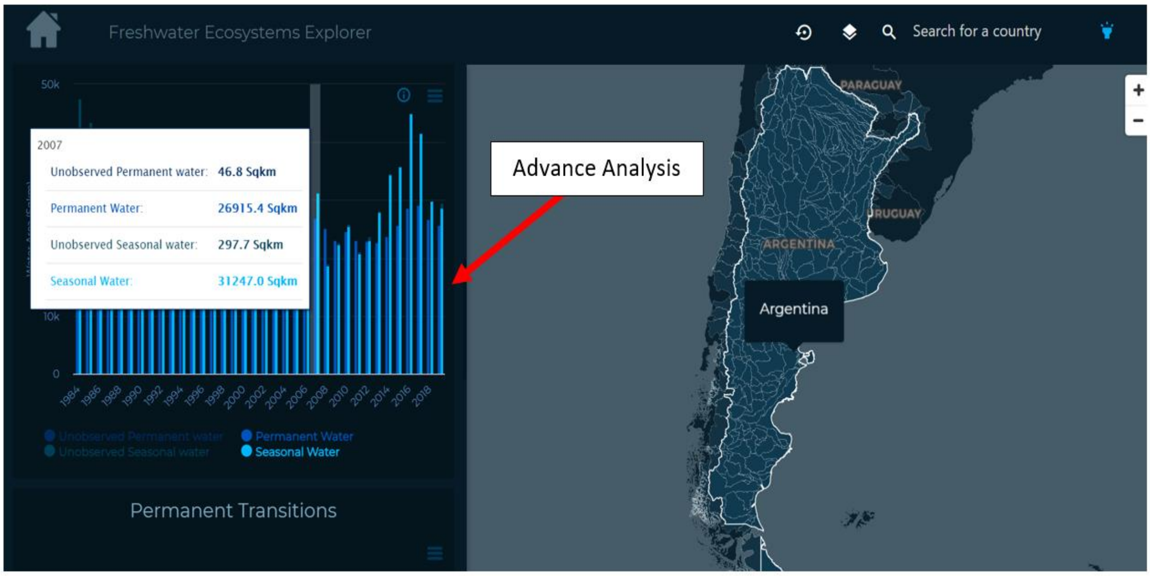

Figure 4.11: Graphical representation of the freshwater ecosystem data in Argentina.

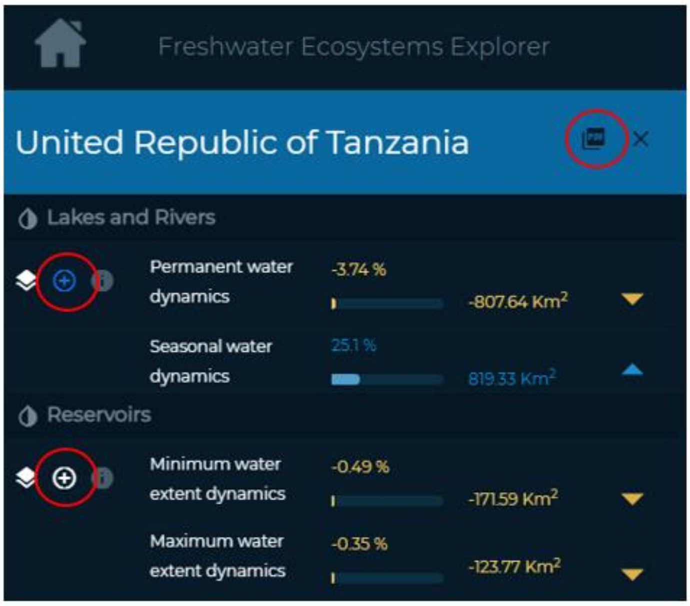

Figure 4.12: Icons to access and download the advance analysis data.

F. Conclusion

In light of the above, having free and open access to such an advanced data portal, with freshwater ecosystem-specific data, allows practitioners across the globe to access useful country-specific data, thereby increasing their capacity to develop, manage and implement data-informed protection, mitigation and management plans, including in cases where in-country data may be limited. The portal also offers an opportunity for practitioners to compare outcomes across countries and regions. This, combined with an awareness of policies and frameworks implemented in countries that have made significant progress towards SDG 6.6.1 targets, can prove useful and has the potential to inform the adoption of national and subnational strategies.

Recommended websites

1. SDG 661 Freshwater Ecosystems Explorer: www.sdg661.app/
2. United Nations Environment Programme, 2021. Case stories: https://stories.sdg661.app/

Recommended reading

1. SDG 6.6.1 Freshwater Ecosystems Explorer platform – Products and methods: www.sdg661.app/productsmethods
2. UNEP, 2021. Story maps:
   - Water quality (Lake Titicaca): https://stories.sdg661.app/#/story/1/0/0
   - Loss of permanent surface water (Australia): https://stories.sdg661.app/#/story/0/1/0
   - Mangroves loss (Myanmar): https://stories.sdg661.app/#/story/2/0/0