Enhanced wetland monitoring, assessment and indicators to support European and global environmental policy

SWOS
Satellite-based Wetland Observation Service

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Citation

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The report summarises how SWOS can ensure a better understanding of wetland ecosystems, and thereby help to trigger further policy developments by improving key elements for wetland management.

Executive Summary

The 2019 report on ***Enhanced wetland monitoring, assessment and indicators to support European environmental policy*** identifies the links between the Horizon 2020 Satellite-based Wetland Observation Service (SWOS) project outcomes (tools, methodologies and indicators) and existing policy frameworks at European and global levels. It aims to contribute to the refinement of EU Strategies and Directives to better integrate wetland ecosystems, contribute towards a European environmental model for wetland management and maintenance of their ecosystem services, and guide action towards achieving no-net-loss and restoration targets and objectives for wetland ecosystems. The report summarises (in four chapters) how SWOS can ensure a better understanding of wetland ecosystems, and thereby help to trigger further policy developments by improving key elements for wetland management.

Between 2015 and 2018, the Horizon 2020 SWOS project has supported policies by developing and applying science-based methods that aim at standardising wetland definition, identification, delimitation, and delineation. The primary outputs of the project are satellite-based monitoring tools (**SWOS toolbox[1], GEO-Wetlands Community Portal[2]**) to enable improved wetland assessment and monitoring capabilities, as well as their application in management and reporting at different scales, and by different users. In addition, the SWOS project includes a capacity-building component to facilitate the uptake of the tools by users. This report presents the project's technical results (Chapter 3), as well as applied examples of the improved capabilities for wetland conservation and restoration needs (Chapter 4). These two chapters are preceded by an introduction (Chapter 1) and a review of the global and EU policies related to wetlands, including a perspective on the post-2020 agenda (Chapter 2).

Below, a summary is presented for each chapter. We hope interested readers, professionals and policy-makers will find in this report both practical tools and related conceptual knowledge to assist the support and implementation of global, EU and national wetlands-related policies, or to develop new ones in the near future.

State of wetlands and the role of policy (Chapters 1 and 2)

Wetlands are crucial for their role in providing water-related ecosystem services. Their part in erosion control and sediment transport, water filtration and regulation are a few of the many valuable services delivered by wetlands. Despite their multiple values to humankind, wetlands continue to be degraded or lost

1. http://swos-service.eu/documents_mapping-software/
2. http://portal.swos-service.eu/

due to anthropogenic pressures including overexploitation, pollution, habitat loss due to changes in land use, and climate change impacts.

The compilation of wetland trend analyses by the Ramsar Convention estimates that the global extent of wetlands has declined between 64 and 71% in the 20th century. These downward trends in global wetland extent arise from increased wetland usage by humans and the lack of specific policy targets and objectives, particularly at regional scales, to address wetland degradation and propose clear measures for restoration and conservation. The European Commission's 2015 'State of Nature' communication highlighted how conservation status assessments show that 51% of habitats related to wetlands have unfavourable status. The EU Biodiversity Baseline 2010 indicates that 73% of wetland habitats and 64% of wetland species have an unfavourable status. Hence, measures to meet the goal of ensuring favourable conservation status of these species and habitats are urgently needed to increase the extent and improve the ecological condition of wetlands across Europe, including areas within the Natura 2000 network.

Opportunities should be sought through the future development of existing environmental policies to ensure the conservation of all wetland ecosystems, including grasslands and coastal wetlands that are not currently protected. Wetland resilience could be further advanced by a new wetland restoration policy that addresses current gaps and by providing solutions for more effective wetland restoration and resilience, such as Natural Water Retention Measures or green infrastructure (e.g. nature-based solutions). Nevertheless, in Europe, there are no environmental policies with a specific focus or clear objectives and targets for wetlands which instead are dealt with amongst other habitat types. Therefore, the effective protection, conservation and restoration of European wetland ecosystems becomes even more challenging and requires innovative methodologies and techniques, such as those presented here, to facilitate their attainment. Through the SWOS project outcomes described in this report, background information can be accessed to establish clear links between the Birds and Habitats Directives (Natura 2000 network), the Water Framework Directive, the Floods Directive, as well as global frameworks such as the Ramsar Convention and the Sustainable Development Goals.

Contribution to wetlands post-2020 agenda (Chapter 2)

This SWOS report looks beyond the current global and EU policy framework that aims at 2020 as a reference year for many targets and actions. The post-2020 agenda at the EU level focuses strongly on progress towards a resource-efficient, low-carbon economy to achieve EU environmental objectives. However, this currently lacks clear policy objectives towards protecting biodiversity, natural capital, and human well-being.

The SWOS project fulfils the need for better wetland ecosystem observation and quantification through monitoring and assessment by applying spatial information technologies in Europe. The outputs are mechanisms to support both current reporting obligations as well as preparations for the post-2020 agenda with suitable environmental monitoring capabilities and information.

From an international perspective, focus on the conservation and protection of wetlands is included in the UN Sustainable Development Goals (SDGs). Indicators, measures and policies are agreed globally through Multilateral Environmental Agreements, most prominently the Ramsar Convention and the Convention on Biological Diversity (CBD).

Under SDG 6, which seeks to ensure the availability and sustainable management of water and sanitation, Target 6.6 focuses on the critical importance of water-related ecosystems for the regulation, cycling and provision of freshwater, as well as other ecosystem services.

Furthermore, wetlands are among the highest priorities of ecosystems to be addressed by the UN Convention to Combat Desertification "Land Degradation Neutrality" (LDN) principle (also targeted under SDG 15), due to their historic declining trends and continuing threats. The SWOS project has developed indicators and tools that specifically help to measure the extent of wetland ecosystems.

SWOS tools and methodologies (Chapter 3)

The SWOS products, tools and services provide fundamental knowledge to support a more complete consideration of wetland ecosystems by EU environmental policies, namely:

- Definition of wetland ecosystem delimitation;
- Improvement of wetland ecosystem classification;
- Mapping of ecosystem delineation as a prerequisite for wetland inventories to provide better information on effective wetland extent and its trends; and
- Improvement of wetland ecosystem condition and pressure assessments based on harmonised indicators.

The SWOS project proposed a "hydro-ecological definition" of wetlands as a basis for the delimitation of these ecosystems[3] as a starting point for an ecosystem-based assessment. The SWOS project addressed the crosscutting nature of wetlands by developing a common and improved MAES classification, modifying existing classes and adding relevant wetland classes[4]. This nomenclature proposal, including crosswalks to other classification systems (e.g. Ramsar, FAO Land Cover Classification System), together with mapping tool capabilities (SWOS toolbox), enables users to map and report under different policy frameworks and can assist in the standardisation of wetland monitoring methodologies. Additionally, it allows a more detailed definition of wetland classes using the latest technological developments through the EU Copernicus Programme (i.e. high-resolution satellite-based data), filling knowledge gaps and ultimately helping to validate and produce case studies in different European regions.

SWOS applications: filling the gaps for wetland-specific actions (Chapter 4)

The SWOS project provides mapping tools for a variety of end users, including local managers, national authorities, and NGOs. These tools have been developed in line with user requirements and cover a variety of applications. The main mapping products (land use and land cover, water quality, surface water dynamics, soil moisture) and indicators will serve reporting and monitoring obligations of different policies at European and global levels. This applies to monitoring total wetland extent in the context of the Sustainable Development Goals as well to mapping potential wetland areas. Furthermore, several methodologies for the assessment of ecosystem service indicators relevant to wetlands have been proposed, such as flood regulation potential and habitat maintenance.

3. http://swos-service.eu/wp-content/uploads/2016/06/SWOS_Wetlands-delimitation-guidelines_FINAL_v1.1.pdf
4. http://swos-service.eu/wp-content/uploads/2017/05/SWOS_MAES-wetland-component-v1.2.pdf

10 Messages for Policy-making

Wetlands as ecosystems

❖ Message 1 ❖

The importance of wetlands

Wetlands are globally recognised as areas of high biodiversity and providers of unique ecosystem services. The efforts led by the Ramsar Convention (established in 1971, being the oldest multilateral environmental agreement and the only one focusing on wetlands) specifically seek to reverse the declining wetland surface trends worldwide.

❖ Message 2 ❖

The ecological value of wetlands

Despite covering about 6% of the land surface and being geographically scattered, wetland ecosystems provide important connectivity between the air, land and water-related habitats, and therefore mitigate anthropogenic pressures and deterioration.

❖ Message 3 ❖

Global change impacts

Under a variety of global change scenarios, water-related risks to society are increasing. These include pollution, water scarcity, and more frequent droughts and floods. Improving the management of wetlands is important because their degradation exacerbates these problems.

❖ Message 4 ❖

The delimitation of wetland ecosystems

The “hydro-ecological” setting of wetlands (including their wetness and flow characteristics) is an important factor for their delimitation. Wetlands can otherwise be overlooked, for example when in a complex of other ecosystem types or in a degraded state. SWOS has demonstrated this in its approach to delimitation.

Wetland mapping and monitoring

❖ **Message 5** ❖

Improved nomenclatures

Wetlands are cross-cutting by nature, connecting different ecosystem and habitat types, as well as different policy targets. Wetlands must therefore be identified and mapped in a consistent way. SWOS has addressed this need by improving the definition of MAES wetland types and linking them to other classification systems.

❖ **Message 6** ❖

Feasibility of mapping

Technological developments, for example through the EU Copernicus Programme, hold significant potential for satellite-based mapping of wetland habitat classes. SWOS has helped to harness this potential, including through identifying specific limitations and solutions to overcome them.

❖ **Message 7** ❖

Ramsar site designation

Local and national authorities are obliged to designate Ramsar Wetlands of International Importance and ensure their effective management. SWOS provides tools and services to support this process and support international cooperation on transboundary wetlands.

❖ **Message 8** ❖

User and policy-orientation

Mapping tools and information solutions are needed by a wide variety of end users in order to meet wetland conservation and restoration targets set for 2020 and beyond. In engaging a broad user network, SWOS holds a privileged position to provide this support.

Wetland policies

❖ **Message 9** ❖

The support to EU policies

There are clear synergies to be realised between the Birds and Habitats Directives (Natura 2000 network), the Water Framework Directive, the Flood Directive, and other wetland-related policies at the European level. These have been explored by SWOS project outcomes and the background information provided in this report.

❖ **Message 10** ❖

The conservation and restoration of wetlands

It would be desirable to advance the future conservation and restoration of wetlands in a comprehensive manner by better integrating wetland-related concerns into EU and global sectoral policies and ensuring their enforcement through legislation.

The SWOS project has contributed fundamental knowledge in support of the current and future EU environmental policies.

Introduction

Wetland conservation and restoration – knowledge and implementation gaps

Wetlands continue to decline fast and globally in terms of their quantity and their quality (1). There is still an urgent need to conserve and restore wetlands. Cumulative anthropogenic pressures, such as transport infrastructures, urban expansion, agricultural usage and climate change impacts, threaten the sustainability of a whole range of wetlands throughout the world (e.g. wet meadows, tidal marshes, mangroves swamps, deltaic areas) provoking the loss of these unique areas. Additionally, the socioeconomic significance, ecological values, wider benefits and ecosystem services provided by wetlands are often overlooked.

The Ramsar (or "wetlands") Convention provides international recognition of the importance of wetlands globally, and a policy framework to manage and restore them. However, there are still difficulties guaranteeing the conservation of wetlands at regional and national levels since these ecosystem units are not sufficiently identified nor quantified, making it difficult to standardise management approaches. In Europe for example, environmental policies such as the EU Birds and Habitats Directives, or the EU Water Framework Directive, are lacking specific quantifiable indicators to monitor the conservation

The complexity of the term 'wetland'

Historically, there has been a cultural dimension to the definition of the term 'wetland'. This reflects differences in environmental landscapes across Europe, but it can lead to misunderstandings. The existing classification methodologies for these ecosystem units (namely, EUNIS, CLC, or MAES classifications) have given rise to different assessments and policies over time, and such diversity of approaches can hinder their effectiveness. So there is a clear necessity for updated formal definitions and consensus among the diverse EU expert working groups in terms of harmonization of monitoring methodologies. This would lead to a better comprehension of wetland characteristics, ecological value and socioeconomic importance to benefit the implementation of the environmental policies adopted by EU member states.

The Horizon 2020 Project, SWOS, provides a common, improved terminology and wetland monitoring capabilities to standardise methodologies for both EU and national policies.

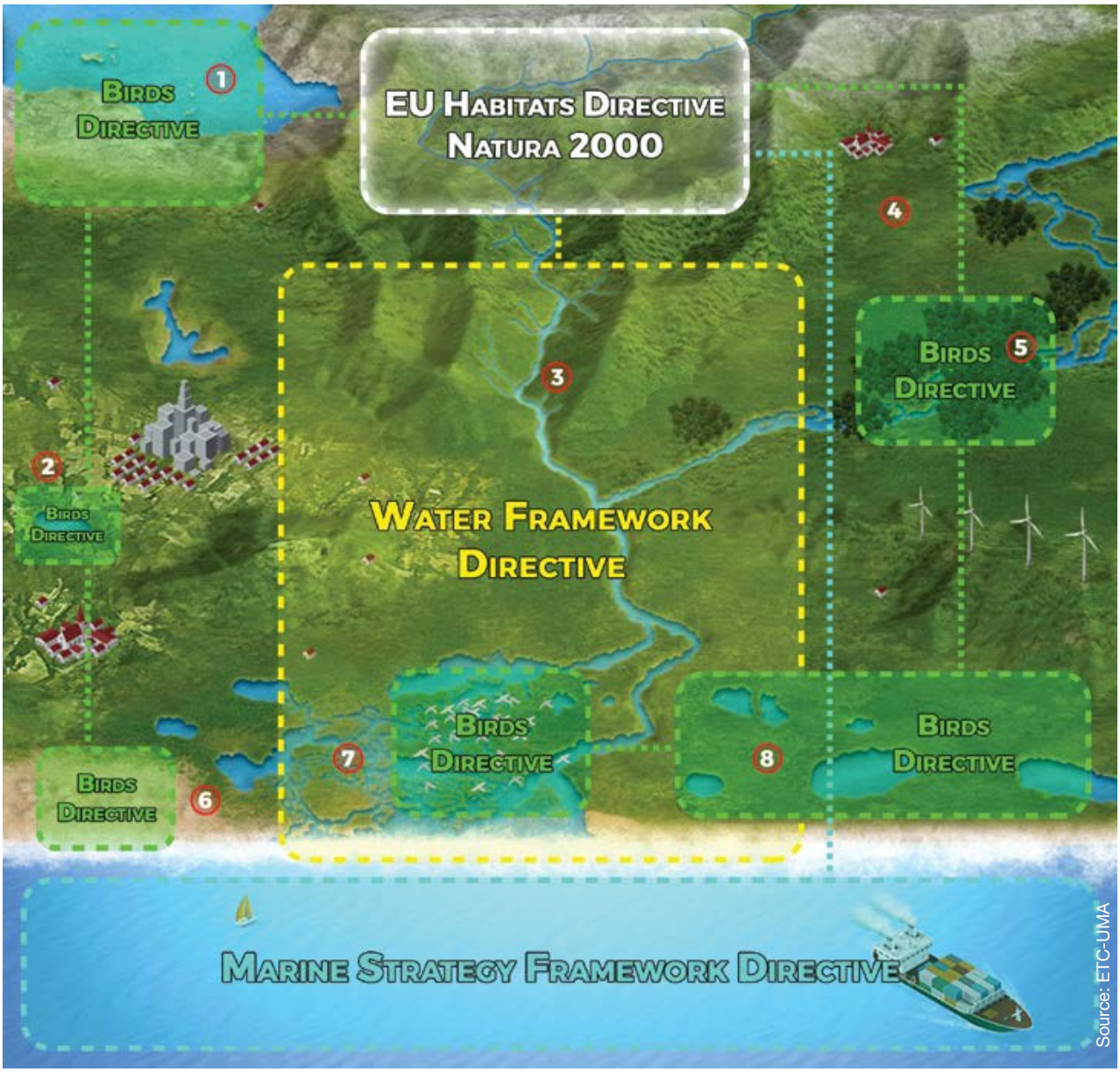


Figure 1-1. Wetlands and policies in the EU: examples of European geographical types of wetlands and most relevant EU environmental policies related to them: 1. Tidal mudflats, 2. Urban wetland, 3. Alluvial meadows, 4. Grasslands, wet meadows, 5. Riparian forest, 6. Dunes, 7. Deltaic areas and 8. Salt meadows and marshes.

and management of wetland areas. Whilst most environmental actions that are derived from the European legislation are relevant to wetland use and conservation, there is no dedicated EU wetlands policy (2). Some habitats protected by the EU Habitats Directive (and therefore included in the Natura 2000 network) are classified as wetlands (e.g. Mediterranean saltmarshes and salt meadows, Boreal Baltic coastal meadows and diverse northern European grasslands), but there remains a clear need for their accurate characterisation and methodologies for their spatial monitoring (Figure 1-1).

The Satellite-based Wetland Observation Service project, SWOS, has focused on the latest technological developments in remote sensing and information system tools (i.e. high-resolution satellite-based data and analyses) to address knowledge gaps in wetland characterisation, and ultimately, to validate and produce demonstration cases for different European regions. The SWOS

project provides technically and scientifically validated mapping tools for a variety of end users, including civil society, private sector, local managers and national authorities, to address wetland conservation and restoration needs. The SWOS project has contributed fundamental knowledge in support of the current and future EU environmental policies in this regard, as well as to the integrated natural capital accounting system strategy (such as the MAES/KIP INCA framework (3). The SWOS project has developed methodologies for the observation of wetland ecosystems and serves to improve the EU Monitoring and Assessment of Ecosystems and their Services (MAES) process (4). These upgraded assessment tools are useful for supporting monitoring, conservation and restoration actions, and can address the wetland ecosystem challenges at a wider European scale, as well as internationally, in the future.

State of wetlands globally and in Europe

A compilation of wetland trend analyses under the Ramsar Convention has given rise to an estimated rate of wetland loss of 64–71% globally in the 20th century, with regional variations, and a higher rate of loss for natural inland wetlands than coastal wetlands (5). The 2016 Living Planet Report indicated that wetland loss may even be as high as 87% over the last 300 years, with a 54% decline since 1900, and a decline of 30–53% between 1970 and 2008 (6). The highest losses have taken place in Europe and Asia. Despite their richness in biodiversity and potential to supply ecosystem services, wetlands are some of the fastest declining ecosystems worldwide. Increasing rates of land conversion to agricultural and urban uses, infrastructure development, water diversion and water pollution are some of the main factors causing wetland degradation and loss (7).

The European Commission's State of Nature communication (8) highlights that wetlands, including mires, bogs and fens, are among the most threatened ecosystems in Europe. Even though the overall extent of wetlands stabilised during the period 2006–2012 (9), the quality of existing wetland ecosystems continued to suffer significantly. In Europe, many wetlands, such as peatlands and other habitats with organic soils, have been lost due to drainage, especially in the temperate zone (Table 1-1). This severely affects important carbon sinks, and wetland restoration efforts are therefore needed to mitigate climate change.

EEA's 2018 State of Water assessment (11) reported that only around 40% of surface waters (rivers, lakes and transitional and coastal waters) show good ecological status or potential, whilst only 38% are in good chemical status. Furthermore, the main significant pressures on surface water bodies are identified as being hydromorphological (40%), despite the initial measures implemented within the second cycle of the EU Water Framework Directive by Member

Table 1-1. Proportion of peatlands and organic soils drained in selected European countries (adapted from reference 10).

Country	% drained	Country	% drained	Country	% drained
Germany	98	Ireland	83	Belarus	66
Netherlands	95	Romania	81	Latvia	66
Denmark	93	France	73	Iceland	63
Austria	85	Lithuania	72	Ukraine	58
Poland	84	UK	67	Finland	54

States to improve water quality or reduce pressures on hydromorphology in catchment areas. The assessment calls for the restoration of hydromorphological conditions, including by reconnecting backwaters and wetlands to restore lateral connectivity between the main river channel, the riparian area and the wider floodplain.

Wetland ecosystem services

Wetlands are areas of high biodiversity; they are home to more than 100,000 freshwater species globally (12), and are essential for many amphibians and reptiles, for bird breeding and migration. While they only comprise about 2% of the EU's territory (13), and 4.3% of the Natura 2000 network area, wetlands are highly important for a wide variety of species. For humans, wetlands provide invaluable ecosystem services, with varying degrees of importance depending on wetland type (see Figure 1-2). For inland wetlands the importance of wetlands for providing food, fresh water, fibre and fuel is evident. Regulating services here are also important, particularly for climate, hydrological regimes, pollution control and detoxification, and natural hazards. Spiritual, inspirational, recreational and educational services are provided by rivers, streams and lakes, whilst significant supporting services are include maintaining habitat for biodiversity, soil formation and nutrient cycling. A different pattern is seen in coastal/marine wetlands, with food being the dominant provisioning service, and climate

Wetland types / Services	Inland Wetlands						Coastal / marine wetlands						Human-made wetlands					
	River Stream	Lake	Peatland	Marsh Swamp	Underground	Salt Marsh	Mangrove	Seagrass	Coral Reef	Shellfish Reef	Lagoon	Kelp	Reservoir	Rice Paddy	Wet Grass	Waste Ponds	Salinas	Aqua Ponds
Provisioning services																		
Food	H	H	H	H	na	H	H	M	M	M	M	L	M	H	H	L	H	H
Fresh water	H	H	L	M	H	L	na	na	na	na	L	na	M	na	na	L	na	Na
Fibre & fuel	M	M	H	H	na	L	H	na	na	na	M	na	L	na	na	L	na	L
Biochemical products	L	?	?	L	?	L	L	?	L	?	?	L	?	na	?	?	L	?
Genetic material	L	L	?	?	?	L	L	?	L	?	?	?	L	L	?	?	L	L
Regulating Services																		
Climate	L	H	H	H	L	H	H	H	M	L	L	na	M	L	L	na	L	na
Hydrological	H	H	M	M	L	M	H	na	na	na	M	na	H	M	L	na	na	na
Pollution control	H	M	M	H	M	H	H	L	L	na	M	?	L	L	L		na	na
Erosion protection	M	M	M	M	H	M	H	L	M	M	L	L	L	M	M		M	na
Natural hazards	M	H	M	H	na	H	H	M	H	M	M	L	L	L	L	na	M	na
Cultural services																		
Spiritual & inspirational	M	H	M	M	L	?	L	?	H	na	M	na	M	L	L	na	M	na
Recreational	H	H	L	M	L	?	?	?	H	na	M		H	L	L	na	L	na
Aesthetic	M	M	L	M	L	M	M	na	H	na	M	na	H	M	M	na	M	na
Educational	H	H	M	M	L	L	L	L	L	L	L	L	H	L	L	L	M	L
Supporting services																		
Biodiversity	H	H	H	H	H	M	M	L	H	M	M	L	M	M	M	L	M	L
Soil formation	H	L	H	H	na	M	M	na	Na	na	na	na	L	M	L	L	L	na
Nutrient cycling	H	L	H	H	L	M	M	L	M	na	M	L	L	M	L	H	L	L
Pollination	L	L	L	L	na	L	M	M	Na	na	?	?	L	L	M	L	L	na

H High M Medium L Low ? Not known na Not applicable

Figure 1-2. Consolidated list of wetland ecosystem services and their relative importance (1).

regulation also being important. Tidal flats, salt marshes and mangroves provide pollution control and detoxification, and, along with coral reefs, protection from natural hazards.

The assessment (and valuation) of these ecosystem services is crucial to integrate the benefits provided by wetlands in the decision-making process. A clear understanding of the spatial distribution of the provision of wetland ecosystem services as well as the areas where these services are demanded allow for prioritising conservation and restoration measures (see Figure 1-3 and Section 4).

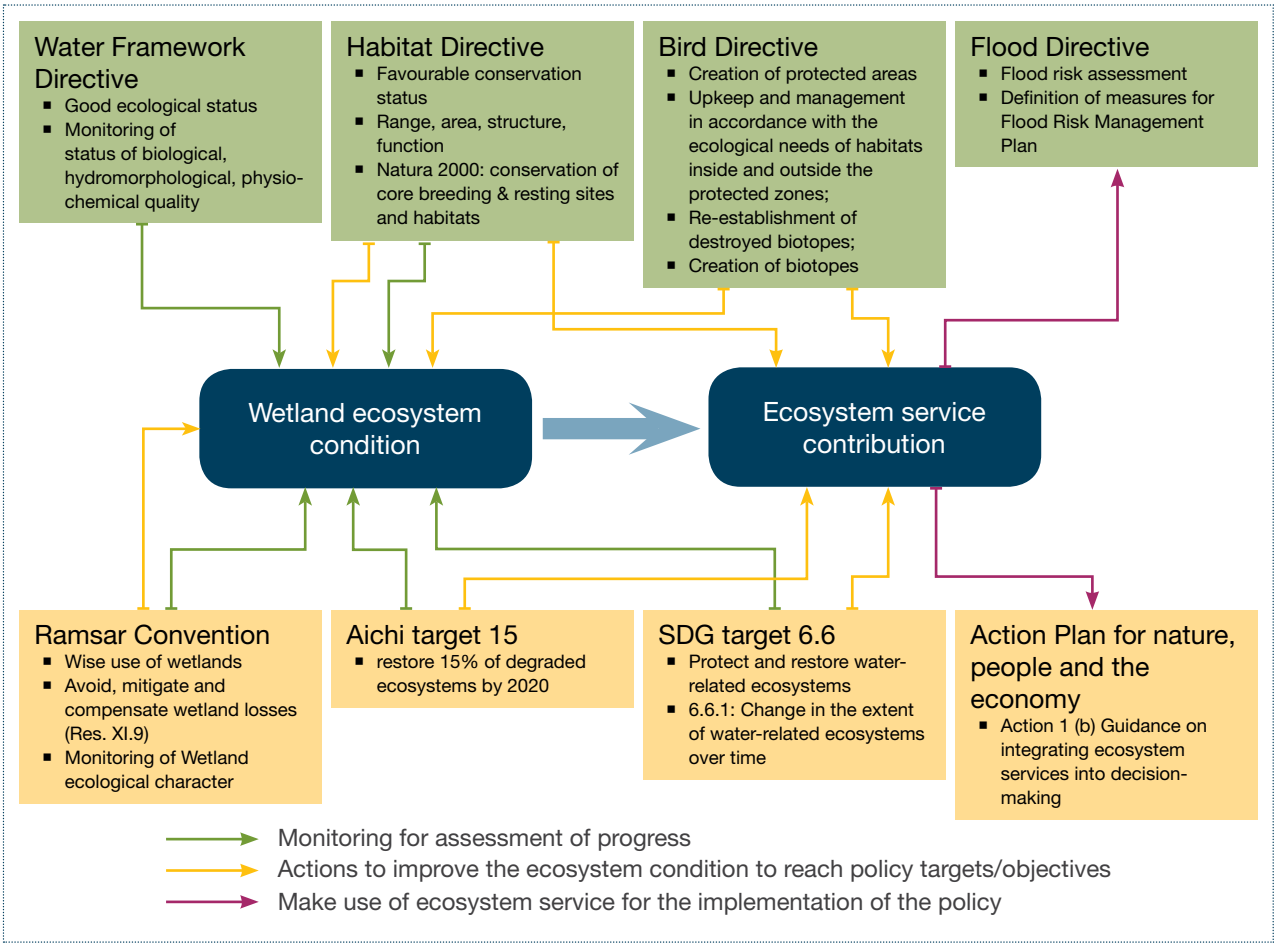
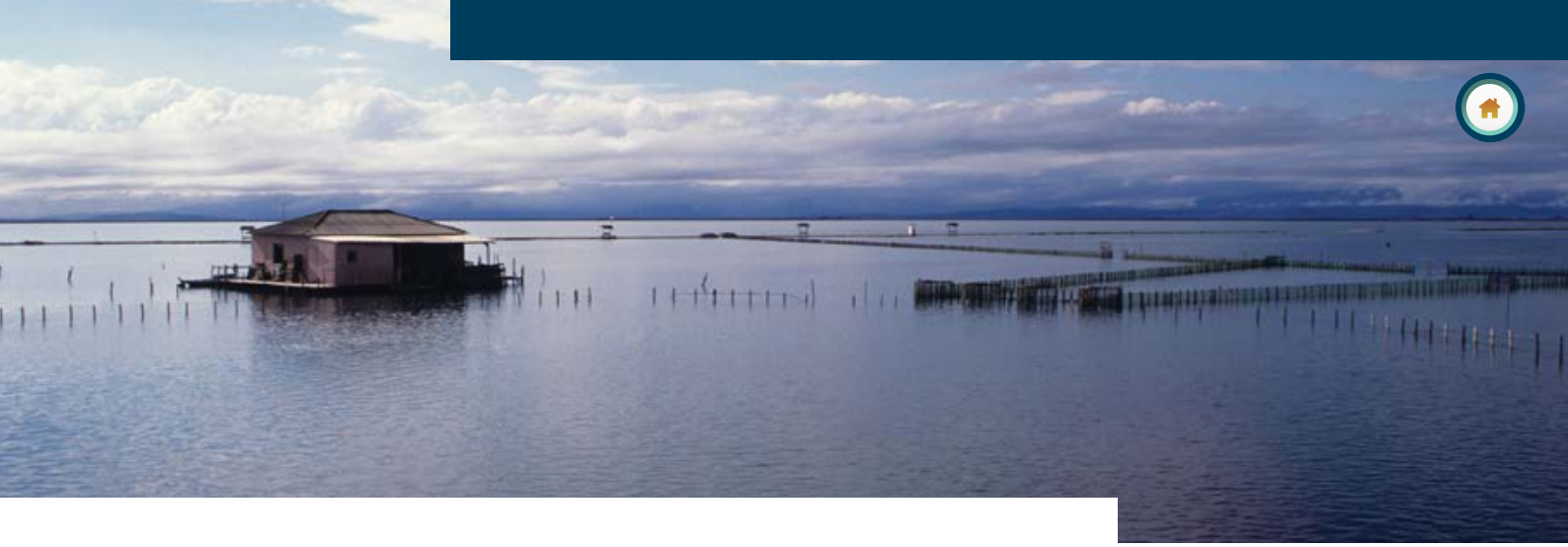


Figure 1-3. Role of EU policies in ensuring prioritization measures for the protection and restoration of wetlands (Source: ETC-UMA).



The evidence gathered in the thematic assessment should serve to inform policy-making on Biological Diversity, Climate Change and Desertification.

Policy Framework for Wetlands Monitoring, Protection and Restoration

Global policies

The Ramsar Convention (the 'wetlands' convention) (14) is the oldest multilateral environmental agreement (established in 1971), and the only one focusing on wetlands. Its mission is 'the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world'. Under the "three pillars" of the Convention, the 169 Contracting Parties commit to work towards the wise use of all their wetlands, designate suitable wetlands for the List of Wetlands of International Importance (the 'Ramsar List', currently comprising 2301 sites, 15), ensure their effective management, and cooperate internationally on transboundary wetlands, shared wetland systems and shared species. All 28 EU member states have ratified the Convention, and over 1000 Ramsar Sites are listed within Europe.

In support of the Ramsar Convention, the Integrated Framework and guidelines for avoiding, mitigating and compensating for wetland losses (16) was adopted at the 11th COP Meeting in 2012. It includes examples of the "avoid-mitigate-compensate" sequence approach for policy, ranging from wetland and biodiversity-related instruments to environmental impact assessments.

The Convention on Biological Diversity (CBD) (17) is the second most relevant international mechanism for the protection of wetland areas. At their 10th meeting of the Conference of the Parties (COP) in 2010 (Nagoya, Aichi Prefecture, Japan), the revised and updated Strategic Plan for Biodiversity for the period 2011–2020 was adopted. The plan established a set of Biodiversity Targets ("the Aichi Biodiversity Targets"), which parties committed to implement through their new or revised National Biodiversity Strategies and Action Plans (NBSAPs). Of significance for wetland conservation is Aichi Biodiversity Target 15 (*by 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced,*

SWOS support to the Ramsar Convention

Member States must delineate and protect wetlands under the Ramsar Convention. To do so, they must develop inventories and characterisation of the protected wetlands, including their delineation. SWOS provides the tools to develop maps of potential wetland areas at different scales (see Sections 3 and 4). The **land use/land cover products** serve to support Ramsar habitat mapping, assessment of threats and pressures to wetlands and the wise use of wetlands.

including the restoration of at least 15 per cent of degraded ecosystems). Targets 5 (*reducing the rate of the degradation of habitats*), 6 (*on aquatic communities*) and 8 (*on pollution*) are also relevant to avoid further wetland degradation.

Another significant decision under the CBD was the adoption of an action plan on ecosystem restoration at the 13th COP in 2016 (Cancún, Mexico). The plan is intended to be a flexible framework to promote the restoration of degraded natural and semi-natural ecosystems. It is to consider a thematic assessment on degradation and restoration by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). This report highlights some of the challenges of assessing the extent and state of wetlands, for example because of artefacts of technological improvements in measurements and non-standardised definition of which wetlands to include. The evidence gathered in the thematic assessment should serve to inform policy-making across all the Rio Conventions (namely on Biological Diversity, Climate Change and Desertification). The restoration of ecosystems, including wetlands, will also feature prominently in the planned regional and global assessments on biodiversity and ecosystem services being undertaken by IPBES (18), and will be further informed by fifth edition of the CBD's flagship publication on biodiversity trends and progress towards the Aichi targets, the Global Biodiversity Outlook.

SWOS support to the Convention on Biological Diversity

SWOS provides valuable tools to support the achievement of restoration targets. Particularly, the **potential wetland layer** aims at supporting the identification of potential restoration areas at different scales. The SWOS capacities regarding **land use/land cover and wetland change mapping** are essential to monitor and report on wetland ecosystem trends and the degree of success of restoration and conservation measures (see Sections 3 and 4).

The Convention on the Conservation of Migratory Species of Wild Animals (or "Convention on Migratory Species", CMS), is a treaty under the aegis of UN Environment with coordinated conservation measures for migratory species throughout their migratory range. Many of these species are waders and other water birds that depend on wetlands for their wintering grounds, breeding areas, and stop-over sites on migration. To the extent that the CMS aims at the conservation of these important habitats, it is therefore furthering the conservation of wetland ecosystems in general. Initiatives under the agreements and less formal instruments that sit within this framework convention include task forces, small grants for projects, working groups and indicators development. Detailed wetland mapping and conservation status assessment can contribute to the meeting of the objectives set in the CMS Strategic Plan 2015–2023.

The UN Sustainable Development Goals (SDGs) target wetlands. SDG 6 specifically focuses on water resources, with its aim to "ensure availability and sustainable management of water and sanitation for all" being fully relevant to wetlands. There are eight targets for SDG 6 covering a range of aspects of sustainable water management, including water pollution reduction, water-use efficiency and equitable access to safe and affordable drinking water. Target 6.6 requires countries to "by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes", therefore recognising the fundamental value of wetlands for the replenishment and purification of water resources. The indicator for measuring progress towards Target 6.6, is Indicator 6.6.1, "change in extent of water-related ecosystems over time".

SDG 15 and Land Degradation Neutrality (LDN)

SDG 15 (Life on land) includes the target to combat desertification and to restore degraded land and soil by 2030, whilst striving to achieve a land degradation-neutral world. The concept of "Land Degradation Neutrality" (LDN) requires that degradation is prevented as far as possible, but also reversed by restoring degraded land to counterbalance unavoidable losses. The historic trend of declines and continuing threats places wetlands among the highest priority ecosystems to be addressed by the LDN principle.

SWOS support to the UN 2030 Agenda for Sustainable Development

Satellite-based wetland observation is an efficient tool to measure wetland extent from local to international levels. The SWOS toolbox includes a **wetland extent indicator**, which allows users to make calculations relevant to SDG indicator 6.6.1 at different scales (see section 3). The SWOS capacities to map **water quality** (see service case in Section 3) as well as **land use/ land cover and its changes** around wetland ecosystems allow reporting on the degree of degradation of wetland ecosystems.

The Paris Agreement negotiated at the 21st COP of the UN Framework Convention on Climate Change (UNFCCC) and adopted on 12th December 2015 called on the Parties "to achieve a balance between anthropogenic emissions by sources and removals by sinks of Greenhouse Gases (GHG) in the second half of this century" (Article 4(1)) and "to take action to conserve and enhance, as appropriate, sinks and reservoirs of GHGs" (Article 5(1)). The Nationally Determined Contributions (NDCs) should set out countries' measures to meet the emissions reduction targets through agricultural, forestry and other land uses. The development of a rulebook in 2018 provides a transparent framework for countries to describe and report on these reductions. Whilst there has been a justifiable emphasis within the land use sector on reducing emissions from deforestation and forest degradation (19) (REDD+), the importance of wetland ecosystems as natural

The use of ecosystems and biodiversity as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change.

sinks in the carbon cycle has been recognised by the International Initiative for Blue Carbon (20) and the Global Peatlands Initiative (21). Also, the integrity of wetlands and other ecosystems is not only important for climate change mitigation, but also adaptation, and this is recognised in the Paris Agreement and their NDCs. In this regard, the importance of agricultural and land-based actions in the NDCs was also noted at the 13th CBD COP. The concept of ecosystem-based adaptation (EbA) was formalised by the CBD in 2009 and defined as "the use of ecosystems and biodiversity as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change ". A review of the intended NDCs submitted to the United Nations by 189 countries indicated that 109 of them included ecosystem-oriented visions for adaptation, in 23 cases with EbA being referred to explicitly (22). EbA measures for wetlands are numerous, whether in coastal environments (e.g. mangrove forests for improved protection from storm surges) or inland (e.g. wetlands for water storage, flood amelioration and fisheries).

SWOS support to UNFCCC

The ideas for **peatland mapping and monitoring** developed in SWOS are a crucial contribution to assess state and trends of these wetland ecosystems, an important carbon sink globally (see Service Case in Section 4).

To minimise flooding, SWOS provides tools and mapping products to assess the capacity of wetlands and other ecosystems to regulate floods and avoid disaster in floodplains and coastal areas. Furthermore, SWOS enables the mapping of historical flood events using the surface water dynamics mapping product (see Sections 3 and 4).

The UN Convention to Combat Desertification (UNCCD) also provides a clear agenda to reverse and prevent desertification and land degradation by establishing the principle of Land Degradation Neutrality (LDN), which has been enshrined in SDG 15 (Life on land) where wetland areas play an important role.

The Sendai Framework for Disaster Risk Reduction 2015–2030 (23), adopted at the 3rd UN World Conference on Disaster Risk Reduction in 2015, recognises that investing in wetlands and the ecosystem services they provide is a cost-effective way to reduce disaster and climate risks and build resilience to extreme climate events.

European policy and legislation

The EU Biodiversity Strategy to 2020 aims to deliver on global biodiversity commitments under the Convention on Biological Diversity and related Aichi Biodiversity Targets. All six areas of the EU strategy on biodiversity targets are relevant to wetlands: the full implementation of EU nature legislation (Nature Directives) (Target 1); maintaining and restoring ecosystems and their services (Target 2); more sustainable agriculture (Target 3), forestry and fisheries (Target 4); tighter controls on invasive alien species (Target 5), and a bigger EU contribution to averting global biodiversity loss (Target 6). The EU strategy stressed the need to take full account of the economic and social benefits provided by nature and to integrate these into reporting and accounting systems. Particularly, the Mapping and Assessment of Ecosystems and their Services (MAES) (24) working group and process was established by the European Commission to support member states in the mapping and assessment of ecosystems within their national territories (Target 2, Action 5).

In the case of wetlands, the ecosystem services and benefits are well articulated and described, including water supply, water purification and flood protection, opportunities for recreation and tourism (because of the amenity value of wetland landscapes), biodiversity conservation and carbon

SWOS support to the EU Biodiversity Strategy

SWOS has proposed a modification of the MAES ecosystem classification to enhance the mapping and monitoring of wetland-related ecosystems. This new nomenclature (4) is a fundamental step to improve the understanding of wetland ecosystems in the EU, (e.g. addressing water regime questions to differentiate grasslands based on their wetness condition). Users can apply the **MAES nomenclature** in the SWOS toolbox and produce MAES ecosystem maps at different scales. Furthermore, different methodologies have been developed to assess the capacity of wetland ecosystems to deliver crucial services, e.g. flood regulation and habitat maintenance (see Section 4).

sequestration (25). The EU strategy expresses concern at the increasing deterioration of wetlands and other habitats of special protection status, which should therefore be prioritised for urgent measures.

Both the Birds Directive and Habitats Directive (EU Nature Directives) prescribe actions that support the conservation and restoration of wetlands. The Birds Directive Article 3 requires EU Member States to preserve, maintain and re-establish sufficient extent and diversity of habitats for all wild birds, whilst the Habitats Directive contains Article 10 on improving the ecological coherence of the Natura 2000 network and Article 6.4 on compensatory measures. Under the latter article, Member States are required to report on compensation measures taken for projects having a negative impact on Natura 2000 sites or on derogations they may have applied to the strict protection measures. Wild bird species protected by the Birds Directive, and habitats of community importance and priority protected by the Habitats Directive, include many associated with wetlands. For the Habitats Directive, 47 of the 233 habitat types listed in its Annex I (or 20%) are wetland habitats, and about 290 species are linked to wetland ecosystems (26). The EU Biodiversity Baseline

(based on Article 17 reporting) shows that 73% of those wetland habitats and 64% of wetland species have unfavourable status. Hence, measures to meet the goal of ensuring favourable conservation status of these species and habitats are urgent and will improve the extent and ecological condition of wetlands across Europe, including areas within the Natura 2000 network.

SWOS support to the Nature Directives

SWOS supports the implementation of the Nature Directives and the Action Plan for nature, people and the economy by building capacity for monitoring wetland ecosystem area, range and status indicators of importance to the Directives. SWOS offers innovative methodologies for the identification of potential restoration areas by using the **potential wetland layer** and producing relevant spatial datasets to monitor **land use and land use changes** in and around Natura 2000 sites (see Sections 3 and 4).

The 2016 fitness check of the Nature Directives considered that they are fit-for-purpose but in need of substantial improvements in their implementation. The resulting ***Action Plan for nature, people and the economy (27)*** and accompanying Factsheets (28) seek to address this implementation gap, and includes Action 1b to develop and promote guidance on 'integrating ecosystem services into decision-making', and Action 3 to 'improve knowledge, including through enhanced and more efficient monitoring, and ensure public online access to data necessary for implementing the Directives (e.g. satellite imagery from the Copernicus programme). More specifically, under Action 3, the EC and EEA will 'assess the most recent progress in satellite-based remote sensing as a support for better implementation of the Nature Directives, develop a pilot online tool for a near real-time tracking of changes to high-nature value grasslands in Natura 2000 sites and support the generation of relevant spatial datasets to monitor land use and land use changes in and around Natura 2000 sites under the EU Space programmes (2017-2019)'. A further Action (12) seeks to provide guidance to support the deployment of green infrastructure for better connectivity of the Natura 2000 areas, and support nature-based solutions projects through EU research and innovation policy and Horizon 2020 funds. The implications of these actions for wetlands are further discussed under the EU Green Infrastructure Strategy.

The EU Water Framework Directive (EU WFD) combined all previous European legislative instruments on the management of water

Natural Water Retention Measures (NWRM)

Supporting the implementation of the EU WFD as well as the EU Floods Directive, Natural Water Retention Measures (NWRM) are defined as 'multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes'. The NWRM are aimed at reducing the vulnerability of EU waters to floods and droughts, recognising that grey infrastructural solutions cannot provide 100% protection alone. The NWRM can provide additional benefits, such as improved water and soil management at the farm level. The measures are to be applied within the framework of River Basin Management Plans for the EU WFD and Flood Risk Management Plans under the EU Floods Directive.

SWOS support to the Water Directives

SWOS can provide innovative tools to measure **water quality** at different scales (see Section 4). This may support improved monitoring of the status of European water bodies. For the EU Flood Directive, SWOS provide tools and **mapping products to assess the capacity of wetlands and other ecosystems to regulate flooding**. This mapping is a first step in identifying and defining Natural Water Retention Measures in the Flood Risk Management Plans. SWOS enable the mapping of historical flood events using the surface water dynamics mapping product, which could serve as input data for flood risk assessments.

resources. Its overall goal is the protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater. It seeks to ensure that all aquatic ecosystems and, regarding their water needs, terrestrial ecosystems and wetlands, attain 'good status', initially by 2015. So far, it has proven to be a valuable policy instrument for maintaining and restoring riverine wetlands. Central to the implementation of the EU WFD was the designation of River Basin Districts and their management plans. As a first step, countries defined and delineated the types of wetlands and open water bodies present within each district (i.e. catchment areas). A WFD cyclical management planning process then involves a characterisation and assessment of impacts on the districts, environmental monitoring, the setting of environmental objectives, and the design and implementation of protection and restoration measures. Close to the EU WFD policy the EU Floods Directive implementation plays a major role implementing measures for flood regulation that includes the consideration of wetlands as Natural Water Retention Measures.

Under the EU Climate and Energy Framework, the new Land Use, Land Use Change and Forestry (LULUCF) package proposal (29) aims to contribute to meeting the EU's commitments under the Paris Agreement, that is, to achieve at least 40% domestic reduction in GHG emissions (to 1990 levels) by 2030. Land-based activities account for 10% of total GHG emissions in Europe. Under Article 2 of the LULUCF proposal, Member States will be required to report on emissions and removals of GHGs between 2021 and 2030 from the following land accounting categories (30):

- Afforested land (including wetlands converted to forest land)
- Deforested land (including forest land converted to wetland)
- Managed cropland (including wetland converted to cropland and cropland converted to wetland)
- Managed grassland (including wetland converted to grassland and grassland converted to wetland).

In addition, Member States may choose to include emissions and removals from the managed wetlands in their accounts. The managed wetlands are defined as land use reported as remaining wetland, settlement, other land converted to wetland and wetland converted to settlement and other land.

SWOS support to the LULUCF package

Land use/land cover mapping (including **mapping and monitoring of peatlands**, see Service Case in Section 3) are important tools with which SWOS can support the LULUCF policy.

The Environmental Impact Assessment (EIA) Directive (85/337/EEC, amended by Directive 2014/52/EU) is in force since 1985 and applies to a wide range of defined public and private projects. The EIA procedure ensures that the environmental consequences of projects are identified and assessed before development consent is issued. The public can give its opinion and the results of the consultations are taken into consideration in the development consent procedure of the project. The public has to be informed on the decision. The EIA Directive outlines the project categories which should be made subject to an EIA, the procedure that shall be followed and the content of the assessment. The EIA procedure consists of several stages during which the developer and the Competent Authority of a Member State exchange information about the characteristics of the project before the development consent. Of particular interest in the context of wetland ecosystems is the stage of submission of environmental information with a focus on the description of the environment and significant effects on the environment of a project. Wetlands are among those ecosystems often affected by large-scale projects. Hence, detailed information about the condition of and potential threats to the wetland ecosystem is crucial.

SWOS support to the EIA Directive

Wetland condition indicators such as wetland extent can provide valuable input information to include in an EIA. These indicators as well provide support when it comes to the monitoring of the environmental impact of public or private projects.

The EU Green Infrastructure Strategy (a strategically planned network of natural and semi-natural areas) highlights the importance of maintaining and restoring functional ecosystems as a foundation for a sustainable Europe. It seeks cost-effective alternatives to traditional "grey" infrastructure to benefit both EU citizens and biodiversity. The strategy aims to meet this objective by promoting spatial land use planning and territorial development and nature-based solutions. With the Natura 2000 protected areas as its backbone, the strategy seeks to ensure the presence of patches of representative vegetation types, thus establishing ecological networks and flows that underpin the ecological integrity of the wider landscape. The strategy is essential to meeting Target 2 of the EU Biodiversity Strategy, which requires that 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems', and

... water risks to society are increasing, including pollution, water scarcity and more frequent droughts and floods.

SWOS support to the Green Infrastructure Strategy

SWOS mapping tools, particularly the **potential wetland layer**, can be used to identify potential restoration areas that can serve as Green Infrastructure elements. At the same time the **land use/land cover products** serve as a monitoring tool to measure the success of restoration and conservation of the EU Green Infrastructure Strategy.

supports other biodiversity targets, such as climate change mitigation and adaptation and combating desertification. Complementary actions under Target 2 of the EU Biodiversity Strategy include the Initiative on No-Net-Loss (Action 7b), aiming to ensure no-net-loss of ecosystems and their services through mechanisms such as compensation or offsetting schemes. However, as identified by the European EEA's Environmental Indicator Report (31), the EU is not making sufficient progress towards meeting its objectives regarding the protection of biodiversity, natural capital and people's health.

How policies can improve wetland management

According to global change scenarios, water risks to society are increasing, including pollution, water scarcity and more frequent droughts and floods. Improving the management of wetlands is important because their current degradation is exacerbating these problems. For example, hydrological disconnection of floodplains from rivers leads to a decrease in dynamic habitat types and biodiversity while enhancing the risk of devastating flood events. Similarly, drained peatlands lose their intrinsic properties in terms of water storage and regulation and carbon storage capacity, not only causing soil subsidence but also contributing to climate change due to the release of CO_2 into the atmosphere from peat oxidation.
Further development and implementation of EU policies can address the drivers of wetland degradation and loss, as well as provide the solutions to prevent, mitigate and reverse this situation. Current EU legislation fails to set specific measurable indicators to monitor wetland conservation over time. On the other hand, a specific wetland restoration policy could encourage more effective restoration of wetland ecosystems and habitats and their ecological functioning. In doing so, this would facilitate the implementation of Natural Water Retention Measures (NWRM) or green infrastructure (32) under EU environmental policies.

Most of these measures and techniques are closely linked to the generic wetland conservation and restoration actions under current EU legislation, such as the EU Water Framework Directive and the EU Floods Directive. Wetlands naturally regulate the flow and transport of water, smoothing peak flows and moderating extreme events (floods, droughts, desertification, salination). NWRM (Figure 2-1) are defined as measures that aim to safeguard and enhance the water storage potential of landscapes, soils, and aquifers, by restoring or creating ecosystems, natural features and characteristics of water courses using natural processes. NWRM are a crucial part of the programme of measures developed under the EU Floods Directive, in terms of reducing flood risks through nature-based solutions. Therefore, NWRM are an effective environmental option for flood risk management, while contributing to reducing the vulnerability of water resources to anthropogenic pressures (e.g. climate change). Additionally, wetlands can improve the hydromorphology at the River Basin scale, supporting the objectives of the EU Water Framework Strategy.

For that reason, a better quality consideration of wetlands within the Flood Risk Management

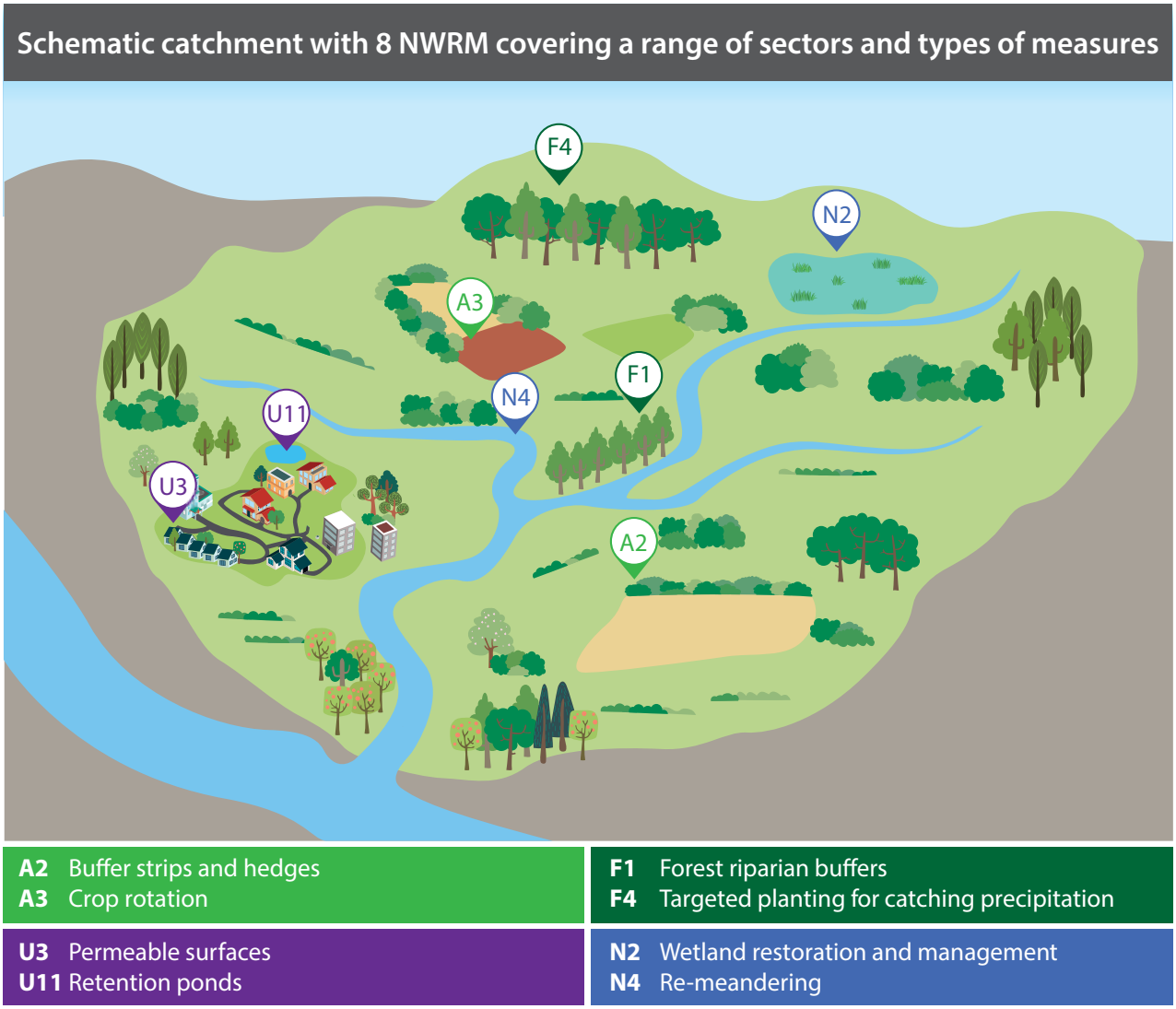


Figure 2-1. Typical examples of NWRM to be applied in a catchment area; for example, under the EU Water Framework Directive or the EU Floods Directive (adapted from reference 44).

Plans (FRMP), as well as within the River Basin Management Plans (RBMP), would be desirable. The characterisation of wetland areas should be improved because wetlands support the achievement of the integrated goals of the EU Green Infrastructure Strategy for nature and biodiversity conservation, restoration, and landscaping.

Overall, the further development of EU environmental policies and the implementation of diverse solutions to combat wetland degradation in Europe should be a priority consideration, as wetlands are important for maintaining many key ecosystem services, including flood regulation. In this regard, the conservation of the capacity for water flow regulation in wetland areas should be more recognised due to their capacity for water purification and flow regulation.

The topics related specifically to wetlands would require concrete policy developments which should start with the harmonisation (e.g. a common wetlands nomenclature) and the necessary improvement of the monitoring capabilities of Member States under the EU policy and legislation.

A new global Strategic Action Plan on Biodiversity 2021-2030

The Convention on Biological Diversity (CBD) requested a proposal be drawn to develop a follow up to the current CBD Strategic Action Plan on Biodiversity for the period 2021–2030 to be agreed upon at the 15th meeting of the COP in 2020. The new plan will be shaped by the 2050 Vision, that "biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people". The future plan is to be developed in the context of the UN 2030 Agenda on Sustainable Development Goals (SDGs) and other relevant agreements.

Post-2020 agenda: a wetlands perspective

The year 2020 is a milestone for environmental policy. The Convention on Biological Diversity (CBD) Strategic Plan on Biodiversity 2011–2020 reaches its fulfilment and is considered to be the most ambitious intergovernmental plan ever for saving nature and nature's benefits on land and sea. Several UN SDG goals and targets are also set for this timeline – notably Target 6.6 on protecting and restoring water-related ecosystems – and the Paris Agreement under the UNFCCC is to be fully implemented by 2020. Whilst there is significant anticipation of the IPBES global assessment on biodiversity and ecosystem services, and hence information on the world's performance in meeting the Aichi Biodiversity Targets, attention is already turning to the post-2020 agenda. The presumption is that many targets will have been missed in 2020 (33). Nevertheless the post-2020 agenda needs to be at least as ambitious, as lessons are learnt from implementation at global and national levels, and as the imperative of protecting nature, biodiversity and ecosystem services becomes ever more necessary in the context of global changes.

It should be noted that stronger progress is being made towards a resource-efficient, low-carbon economy than in protecting biodiversity, natural capital and people's health to achieve environmental objectives. In this regard, the SWOS project fulfils the need of better ecosystem (i.e. wetlands) observation and quantification through monitoring and assessment by means of spatial information technologies (e.g. EU Copernicus space programme) in Europe.

The EEA's Environmental Indicator Report 2017 provides an overview of the EU's progress towards 29 environmental policy objectives. According to the report, many indicators show positive past trends but meeting relevant targets by 2020 remains a challenge. Moreover, the positive trends are related to the financial crisis, which led to lower economic activity in the EU. Looking beyond 2020, EU Member States need to accelerate progress in transforming key systems of production and consumption – especially sectors that have the greatest environmental impact such as food, energy and mobility – whilst enhancing environmental policies.

SDG Target 6.6 is turning around the future of wetlands. Under SDG goal 6 on ensuring the availability and sustainable management of water and sanitation, Target 6.6 focuses on the critical importance of water-related ecosystems for the regulation, cycling and provision of freshwater as well as other ecosystem services. Specifically, it sets out to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes. An indicator (6.6.1) has been defined for Target 6.6, to monitor *the change in extent of water-related ecosystems over time*. Its methodology is being developed and tested under the custodianship

of UN Environment and the Ramsar Convention. Indicator 6.6.1 is a composite indicator including aspects of water quality and quantity (river flow, water quality of lakes and artificial water bodies), as well as the spatial extent of open water and vegetated wetlands (see Sections 3 and 4). Monitoring and reporting against wetland extent and ecosystem health under indicator 6.6.1 and the Wetland Extent Trends Index (WET Index, 34), will help policy- and decision-makers set management objectives for conserving existing wetland resources, as well as restoring wetlands and their condition where they have declined or deteriorated. Implementation of measures for meeting Target 6.6 will substantially contribute to biodiversity objectives and the wider sustainability agenda post-2020.

The post-2020 agenda is an important opportunity to increase synergy and convergence of environmental policy aims, implementation and reporting. The 2030 Agenda for Sustainable Development is already seen as representing an important enabling environment to the implementation of the CBD. Almost all the elements of the Strategic Action Plan on Biodiversity adopted in Aichi are reflected in the SDGs and their targets, and SDGs 14 and 15 are directly related to biodiversity. The future Strategic Plan on Biodiversity will provide continuity and further impetus for mainstreaming biodiversity and ecosystem services.

Land Degradation Neutrality (LDN) (35), in the context of the large-scale restoration of degraded lands, needs to be a central tenet of the post-2020 agenda. The current Strategic Action Plan on Biodiversity targeted a 50% reduction (if not almost 100%) in the rate of loss of natural habitats including wetlands, with degradation and fragmentation being significantly reduced (Aichi Biodiversity Target 5), and the building of ecosystem resilience including the restoration of at least 15% of degraded ecosystems (Target 15) by 2020. Building on these targets, it is widely recognised that a degradation-neutral world is today's absolute requirement, as reflected in the SDG Target 15.3 statement "combat desertification, restore degraded land and soil, including land affected

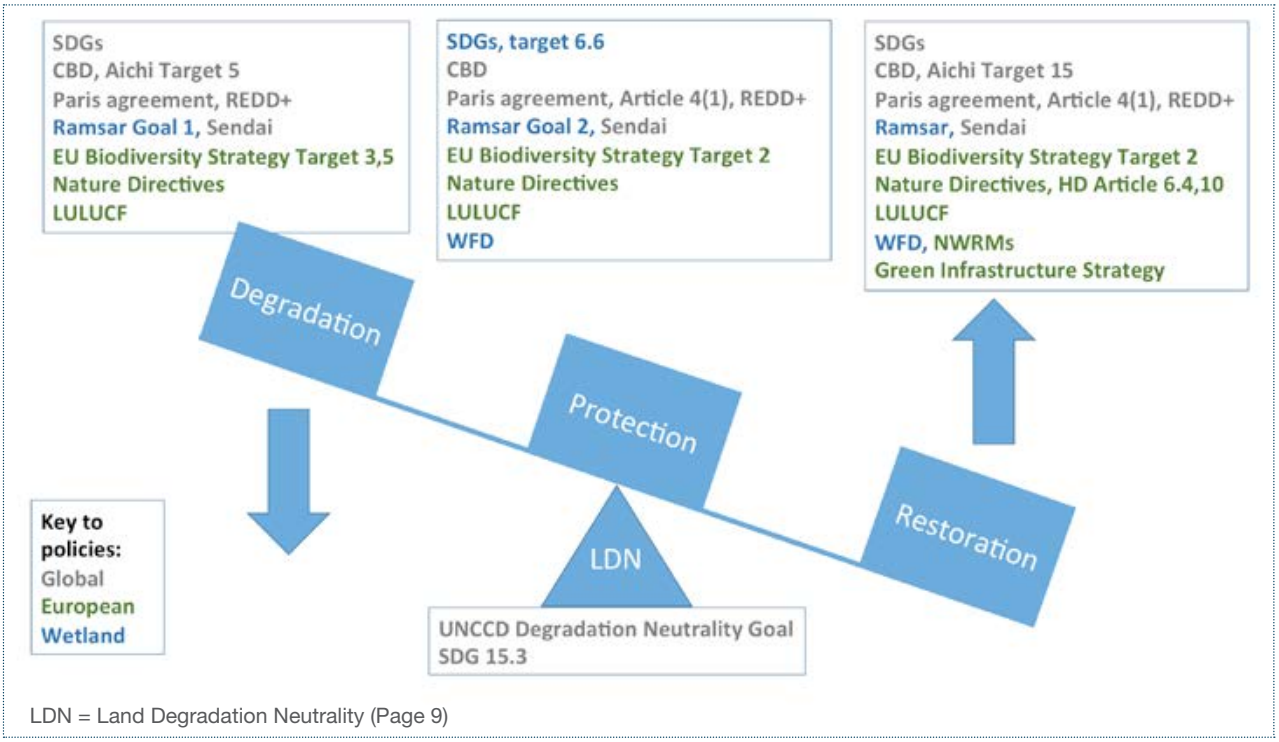


Figure 2-2. Global and European policies, relevant for (wet)land restoration and conservation. (Source: UN Environment WCMC)

by desertification, drought and floods, and strive to achieve a land degradation-neutral world".

Several initiatives are already working towards LDN. The Bonn Challenge that was launched in 2011 by the German Government and IUCN (later endorsed and extended by the New York declaration on Forests at the 2014 UN Climate Summit), targets the restoration of 150 million hectares of deforested/degraded land by 2020 and 350 million hectares by 2030. The principle of Forest Landscape Restoration (FLR) is critical to achieving such a goal. It involves actions that seek ecological integrity and the support of human wellbeing within multi-functional landscapes.

This is not a global commitment, but instead a means to realise existing targets and commitments related to degradation and restoration. This links to the Ramsar Strategic Plan 2016–2024 addressing the drivers of wetland loss and degradation. On the other hand, initiatives such as the Half Earth Project, Nature Needs Half, and Conservation Futures, seek new ways of defining and getting consensus on how and where to safeguard space for nature and biodiversity, and may be important for reinforcing and supporting LDN policy aims.

Figure 2-2 summarises the current international and European policies relating directly or indirectly to wetland conservation and restoration. The policies achieve LDN (or no-net-loss with respect to wetlands) when areas experiencing loss and degradation are balanced by areas undergoing restoration.

Other existing policy agreements and processes stretch beyond 2020 and represent an important context for SDG 6.6 and other biodiversity and ecosystem strategies. Indeed, a stated aim is to have enhanced linkages between the various multilateral environmental agreements (MEAs) and other relevant frameworks. These include the Sendai Framework on Disaster Risk Reduction, the Land Degradation Neutrality (LDN) Goal under the UN Convention to Combat Desertification (UNCCD) and the Paris Agreement under the UNFCCC. Specifically, in the context of wetlands, the Ramsar Strategic Plan for 2016–2024 reinforces the intention of achieving appropriate synergies across the MEAs by streamlining procedures and processes including reporting and implementation.

Scientific evidence and data sharing

The Convention on Biological Diversity (CBD) requested a proposal be drawn to develop a follow up to the current CBD Strategic Action Plan on Biodiversity for the period 2021–2030 to be agreed upon at the 15th meeting of the COP in 2020. The new plan will be shaped by the 2050 Vision, that "biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people". The future plan is to be developed in the context of the UN 2030 Agenda on Sustainable Development Goals (SDGs) and other relevant agreements.

Table 2-1. Post-2020 SWOS contributions on European policy and legislation implementation on wetlands protection and conservation.

EU Policy/ Legislation/ Strategy	Date	Timeline	Objectives and/or targets in relation to no-net-loss of wetlands	Policy measures to be implemented	SWOS policy support
EU Biodiversity Strategy	May 2011 (adoption by EC)	2020	Maintaining and restoring ecosystems and their services (Target 2)	Improve knowledge of ecosystems and their services (Action 1), promoting a European green infrastructure (Action 2), ensuring no-net-loss of biodiversity and ecosystem services (Action 3)	Improved MAES nomenclature LULC mapping of wetland ecosystems
EU Birds Directive	April 1979 (amended in 2009)	(beyond 2020)	Preserve, maintain and re-establish sufficient diversity and area of habitats for all wild birds (Article 3)	Designation of Special Protection Areas (SPAs) as part of the Natura 2000 network	Monitoring of wetland ecosystems Identification of potential restoration areas by using the potential wetland layer
EU Habitats Directive	May 1992	(beyond 2020)	Ensure the favourable conservation status of species and habitats of community importance (including 290 species and 47 habitats associated with wetlands)	Designation of Special Areas of Conservation (SACs) as part of the Natura 2000 network; Article 10 on improving the ecological coherence of the Natura 2000 network, and Article 6.4 on compensatory measures	Monitoring of wetland ecosystems Mapping indicators of pressures and threats
EU Water Framework Directive	October 2000	Initially 2015 and beyond	The protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater, seeking to ensure that all aquatic ecosystems meet ‚good status'	Development, implementation and review of management plans for River Basin Districts. Definition and implementation of Natural Water Retention Measures (NWRM)	Water quality monitoring and assessment Surface water dynamics mapping LULC mapping
Land Use, Land Use Change and Forestry LULUCF package proposal under the EU Climate and Energy Framework	May 2018 (adoption by EC)	2030	Ensure that accounted emissions from land use are entirely compensated by an equivalent removal of CO2 from the atmosphere through action in the sector: the „no debit rule"	Reporting on emissions and removals of GHGs between 2021 and 2030 from the land accounting categories of afforested land, deforested land, managed cropland, and managed grassland (all including conversions to/from wetlands)	LULC mapping Mapping and monitoring of peatlands
EU Green Infrastructure Strategy	May 2013 (adoption by EC)	(beyond 2020)	Restore the health of ecosystems, ensure that natural areas remain connected together, and allow species to thrive across their entire natural habitat	Protection, restoration, creation and enhancement of green infrastructure as an integral part of spatial planning and territorial development whenever it offers a better alternative, or is complementary, to standard/ traditional grey infrastructure	Identification of potential restoration areas by using the potential wetland layer Mapping of wetland ecosystems (LULC)

Table 2-2. Post-2020 SWOS contributions for the development of global policy on wetlands protection and conservation.

Global Policy/ Agreement/ Framework	Date	Timeline	Objectives and/or targets in relation to no-net-loss of wetlands	Policy measures to be implemented	SWOS policy support
2030 Agenda for Sustainable Development (SDGs)	January 2016	2020	SDG 6.6: protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Translation by governments of goals and targets into national legislation; development of action plans	Mapping SDG indicator 6.6.1 using satellite images and the SWOS toolbox (indicator wetland extent)
		2030	SDG 15.3: Combat desertification, restore degraded land and soil ... and strive to achieve a land degradation-neutral world		Mapping SDG indicator 15.3.1 by providing LULC change information about wetlands (% degraded/total)
Convention on Biological Diversity (the Aichi Biodiversity Targets)	October 2010 (adoption of Strategic Plan for Biodiversity 2011-2020)	2020 (2021-2030 SP in preparation)	The rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced (Target 5)	Development of National Biodiversity Strategies and Action Plans (NBSAPs) as mechanisms for delivering the targets at a national level	Mapping LULC and wetland changes to support monitoring of wetland ecosystems
		2020 (2021-2030 SP in preparation)	Ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, including the restoration of at least 15 per cent of degraded ecosystems (Target 15)		Identification of potential restoration areas by using the potential wetland layer
UNFCCC	November 2016	Initially 2025/2030	Act to conserve and enhance, as appropriate, sinks and reservoirs of GHGs (Article 5(1))	Nationally Determined Contributions (NDCs)	Mapping and monitoring of peatland areas
Ramsar Convention (the 4th Strategic Plan)	December 2015 (established in 1971)	2024	Goal 1 of the Strategic Plan addresses wetland loss/degradation and includes four targets*	Designating areas to the List of Wetlands; avoiding, mitigating and compensating for wetland losses	Wetland delineation and inventory product
UNCCD (Strategic Action Plan to Combat Desertification 2018-2030)	December 1996	2030	Achieve Land Degradation Neutrality (LDN), including through the restoration of productivity of degraded land and the improvement of livelihoods of more than 1.3 billion people	National Land Degradation Neutrality (LDN) target setting process**	Identification of potential restoration areas by using the potential wetland layer
Sendai Framework for Disaster Risk Reduction	March 2015 (adoption)	2030	Substantially reduce global disaster mortality and the number of affected people	Promote the mainstreaming of disaster risk assessment***	Flood regulation indicator that supports policies of flood disaster reduction

* ensuring water for wetland ecosystem needs, applying wise use guidelines, and controlling or eradicating invasive alien species; ** including the definition of national baselines, targets and associated measures to achieve LDN by 2030; protection and restoration of wetlands in targeted dryland systems; *** mapping and management into rural development planning and management of, inter alia, mountains, rivers, coastal flood plain areas, drylands, wetlands and all other areas prone to droughts and flooding … and at the same time preserving ecosystem functions that help to reduce risks" (paragraph 30(g)); paragraph 28(d) on transboundary cooperation

SWOS mapping products and derived products and indicators can be used to map the extent of wetlands (and other terrestrial and coastal) ecosystems in Europe and worldwide.

SWOS Tools for Mapping and Assessment

Mapping products

With the aim of moving towards a decreasing trend in wetland degradation, there is a need to **develop better baseline information about the extent of wetland ecosystem concerns** (wetland threats, pressures on wetlands, wetland ecosystem quality decline, wetland loss, etc.). One way to support the development of EU policies focused on no-net-loss of wetlands is to map and assess wetland ecosystems within the context of the EU Biodiversity Strategy. Monitoring and reporting obligations of several directives (e.g. EU Water Framework Directive, EU Floods Directive, and the EU Nature Directives) also assist in this regard, whilst additionally guaranteeing international policy framework compatibility (e.g. SDG 6.6).

SWOS mapping products (profiles presented in Table 3-1), and derived products and indicators (Tables 3-2 and 3-3), can be used to map the extent of wetlands (and other terrestrial and

Table 3-1. SWOS mapping product profiles.

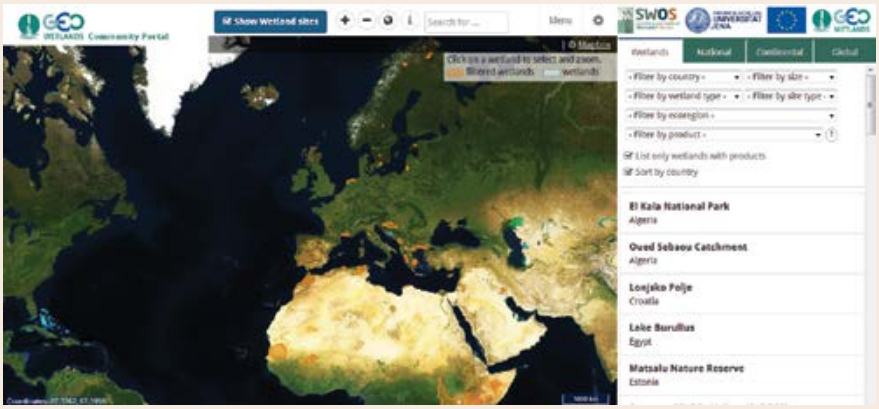
SWOS products	Minimum mapping unit	Temporal resolution	Spatial extent (size of the area to be mapped)	Season to be mapped (Wet/Dry)
Potential Wetland Areas	20m-30m (depending on the input data)	N/A	Site Catchment area National Regional	N/A
Surface Water Dynamics (SWD)	20m-30m (depending on the input data)	Monthly	Catchment area	Wet/Dry
Land Use/Land Cover (LULC)	10m-100m (depending on the input data)	Weekly	Site Catchment area	Wet/Dry
Long-term Land Use/ Land Cover Changes (LULCC)	same as the LULC product (e.g. 10m Sentinel image)	Monthly	Catchment area	Wet/Dry
Short-term LULCC	30m	Weekly	Site and catchment area scale	Wet/Dry
Water Quality (WQ)*	3 km^2	Monthly	Open water**	User driven***
Land Surface Temperature (LST)	1 km	Daily	Site Catchment area	Wet/Dry
Surface Soil Moisture (SSM)	10m	Weekly	Site Catchment area	Wet/Dry

* WQ products are primarily based on MERIS archive (2002-2012), some Sentinel-3 (2017) may be applicable;
** Applicable for open water surface areas of an approximate minimum of 3 km^2, where the water depth exceeds the Secchi depth;
*** Different for different sites depending on latitude and user needs.

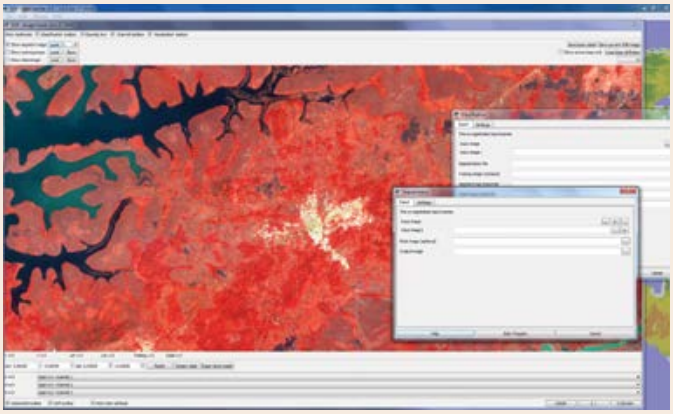
SWOS products & tools

SWOS provides a user-friendly monitoring and information service, including GEOtools, for wetland managers and stakeholders.

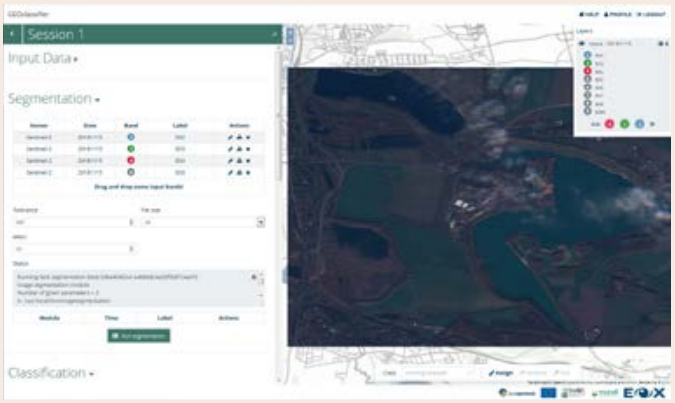
The SWOS project has developed a single entry point to all its mapping products – the GEO-Wetlands Community Portal, accessible through http://portal.swos-service.eu/



The SWOS toolbox provides a suite of powerful tools for processing and analyzing remote sensing images and extracting standardised products, using hierarchical nomenclatures, as well as relevant indicators. It is available as both desktop (https://www.swos-service.eu/documents_mapping-software/) and cloud versions (https://geoclassifier.eox.at).



Desktop version



Cloud version

coastal) ecosystems in Europe and worldwide. SWOS products can also be used to assess the condition of wetlands and pressures exerted upon them, contributing to improved international and national monitoring and reporting (4, 36, 37).

In addition to the mapping products detailed in Table 3-1, several technical guidelines have been produced in the context of SWOS that will serve as important resources for successful wetland mapping and monitoring. For example, a key contribution is the proposed enlargement of the MAES nomenclature.

As a first step, SWOS aimed to enhance, expand and harmonise the MAES nomenclature to fully cover the wide range of wetland ecosystems that exist. To this end, new classes were introduced to the wetland ecosystem nomenclature, such as rice fields, wet grasslands, wet heathlands, and riparian forests. These newly included classes are classed under the MAES nomenclature as belonging to agro-ecosystems, grasslands, heathlands and shrubs, and woodland and forests, but are mapped and assessed as being a part of wetland ecosystems in SWOS. According to the SWOS approach, the wetlands are defined based on their hydro-ecological criteria and can therefore be found under any other ecosystem type of the MAES typology (at Level I). Modifications were also made to some class name definitions, to make them more representative and discrete, and align with relevant wetland research considerations. As a result, the technical document “The wetland ecosystems in MAES nomenclature” was published (4). This document provides a comprehensive list of the wetland

Combined new satellite-based Earth Observation and information technology

New satellite technologies, including the Sentinel missions of Copernicus, together with long-term historical satellite data, add benefits to the mapping of wetland ecosystems. For example: the SAR system Sentinel-1 can capture inundated areas and surface water dynamics; the optical Sentinel-2 satellite is used for LULC and inland water monitoring; and Sentinel-3 provides data on sea and land surface temperature and water colour. Additionally, the Landsat and ENVISAT legacies allow historical assessments of ecosystem changes.

ecosystem classes that SWOS has proposed for integration in the MAES nomenclature along with application guidelines and mapping conventions. Crosswalks between the MAES wetland classes, Ramsar types, and CLC classes are provided to ensure a user-friendly shift amongst each classification.

The guidelines set mapping rules for wetland habitat delineation, where feasible, and the consideration of these habitats within wetland ecosystem assessments. It should be highlighted that the delineation of this nomenclature may not always be operational at its most detailed levels (levels 3 or 4 in the hierarchical typology) when relying on Earth Observation (EO) data, or even when using ancillary data (38). However, the most detailed nomenclature is retained for the sake of completeness, to allow for applications in exceptional cases where a site has abundant ancillary data and there is no risk of confusion between wetland habitats. In most cases however, mapping at higher levels (i.e. levels 1-2) may be the only option for reliable results.

In this context, new satellite technologies, including the Sentinel missions of Copernicus together with long-term historical satellite data, add benefits to the mapping of wetland ecosystems. By making use of the latest EO and IT technology, new standards can be established. The feasibility of EO to support the EC MAES initiative, international conventions (e.g. RAMSAR), and multi-level policies, has yet to be recognised.

Indicators to support ecosystem assessment

The analytical framework for ecosystem condition is the keystone of Target 5 of the EU Biodiversity Strategy to 2020. This is because ecosystem condition is a unifying concept which brings legal requirements about the status of habitats, species and ecosystems, and their capacity to provide ecosystem services, into a common framework. Also included are ecosystems and habitats that are not specifically recognised under European environmental legislation. The fifth MAES report (24) provides operational guidance to the EU and the Member States on how to assess the condition (or the state) of Europe's ecosystems; it also proposes indicators for pressure and indicators for ecosystem condition per MAES ecosystem type.

The added value of the MAES indicator framework is that, for the first time, a comprehensive and consistent list of indicators for ecosystem condition is brought together. The indicators can be used to measure progress against targets of the EU's Biodiversity Strategy. Tables 3-2 and 3-3 present the relation of the SWOS mapping products and derived indicators with the MAES indicator framework. The listed indicators support the integrated MAES ecosystem assessment by better reflecting wetland specific concerns, ensuring the correct delimitation and delineation of wetlands, as well as assessing threats and pressures. Hence, SWOS indicators help to ensure an improved overview of the state of wetland ecosystems in Europe.

The SWOS indicators are not only relevant in the MAES context, but are also relevant in the context of the different policies described above (e.g. SDG, Water Framework Directive). The detailed tables in Annex I and II provides an overview of the degree of relevance of individual indicators to support the measurement of policy targets.

Table 3-2. Summary of SWOS pressure indicators and mapping products (full table in Annex I includes the SWOS sub-indicators). Indicators with an asterisk (*) have been applied in SWOS service cases but are not integrated into SWOS user software.

PRESSURE INDICATORS		
Supported MAES Indicators	**SWOS Indicators**	**SWOS Mapping products**
Pressure: Habitat conversion and degradation (land conversion)		
Change of area due to conversion (%/year) (SEBI 004) Land take (ha/year) (conversion from natural to artificial areas in floodplains or riparian areas) Ecosystem coverage change (%/year) (related to SEBI 004)	Wetland change to Agriculture & Urban	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Wetlands artificialisation	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Change in wetland area	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Anthropogenic Impact (CI)	Potential Wetlands Areas Surface Water Dynamics (SWD) Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
Pressure: Climate change		
Climate impact & sensitivity (CI)	Change in wetland area	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Status of Wetland Threats	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Status and Trend of Land Surface Temperature	Land Surface Temperature trend maps (LST)
Pressure: Pollution and nutrient enrichment		
Exposure to eutrophication (mol nitrogen eq/ha/y)	Status and Trend of Water Quality	Water Quality (WQ)
Pressure: Over-exploitation		
Agricultural intensity pressure on wetlands (CI)	Status of Wetland Threats	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
	Status and Trend of Land Surface Temperature	Land Surface Temperature trend maps (LST)

Table 3-3. Summary of SWOS condition (state) indicators and mapping products (full table in Annex I includes the SWOS sub-indicators). Indicators with an asterisk (*) have been applied in SWOS service cases but are not integrated into SWOS user software.

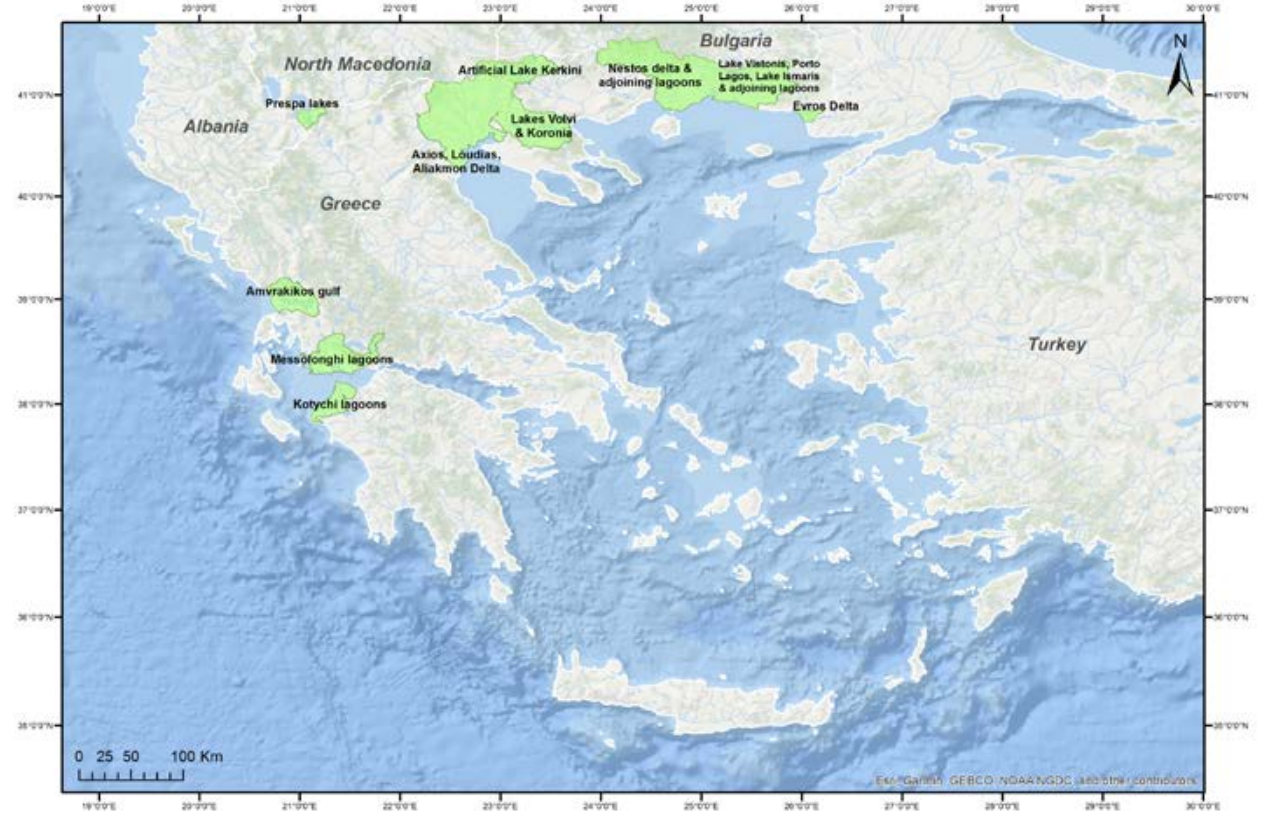
CONDITION INDICATORS		
Supported MAES Indicators	SWOS Indicators	SWOS Mapping products
Ecosystem attributes (biological quality of ecosystems): **Structural ecosystem attributes (general)**		
Landscape fragmentation (CI)	Ecosystem Fragmentation*	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
Wetland connectivity indicator (<10 km from other wetland / >10 km from other wetland)	Wetland connectivity indicator* (<10 km from other wetland / >10 km from other wetland)	Potential Wetlands Areas Surface Water Dynamics (SWD) Land Use/Land Cover (LULC)
Threatened wetland-related habitats (%, number, area)	N/A	Land Use/Land Cover (LULC)
Other	Extent of Open Water Total wetlands extent Change in wetland area	Surface Water Dynamics (SWD) Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)
Ecosystem attributes (biological quality of ecosystems): **Structural ecosystem attributes monitored under the EU Nature directives & Structural ecosystem attributes based on species diversity and abundance**		
Percentage of wetlands covered by Natura 2000 (%) Percentage of wetlands covered by National Designated Areas (%)	Total wetlands extent	Potential Wetland Areas Land Use/Land Cover (LULC) Surface Water Dynamics (SWD)
Conservation status & trends of habitats of Community interest associated to wetlands (%) Conservation status & trends of species of Community interest associated to wetlands (%) EU Population status & trends of bird species associated to wetlands (%) Farmland Bird Indicator (index) (SEBI 001) (AEI2.4.1)	Biodiversity State*	Potential Wetland Areas Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC) *to be used for downscaling EU Biodiversity datasets*
Ecosystem attributes (biological quality of ecosystems): **Structural soil attributes**		
Soil moisture (%)	N/A	Surface Soil Moisture (SSM)

Service Case 1

Mapping and assessment of the 10 Greek Ramsar sites

OVERVIEW MAP

Greek Ramsar sites and their catchment areas



TARGET POLICY

Ramsar Convention

The provision of a suitable map or maps is a requirement under Article 2.1 of the Ramsar Convention, which suggests that Ramsar site maps shall: (i) clearly delineate wetland and non-wetland parts of the designated site; (ii) depict the wetland boundary and the main wetland habitat types with respect to the site's boundary, especially where the wetland extends beyond the site being designated; and, (iii) map land cover and land uses of catchment area.

OTHER RELEVANT POLICIES

Convention on Biological Diversity (Aichi Biodiversity Targets 5 and 8); EU Biodiversity Strategy; SDG 6; Sendai Framework for Disaster Risk Reduction; National Policy and Law (Specific Environmental Studies for the designation of Natura 2000 sites; Designation of small wetlands outside protected areas).

MAPPING PRODUCTS

Land Use/Land Cover at catchment level

SWOS Land Use/Land Cover (LULC) mapping products have been produced for the 10 Greek Ramsar sites, and their catchment areas, for two-time periods (around 1986 and 2016) covering two seasons (dry and wet) per year. The maps have been classified following the MAES nomenclature as modified in SWOS. Based on crosswalks between the MAES classes and the CLC-Ramsar hybrid classification system, the Ramsar mapping products have been created (Figure 3-1).

SWOS INDICATOR

Total Wetland extent

Currently, there are no maps available that depict the wetland and non-wetland areas of Ramsar sites. The total wetland ecosystem extent indicator provides an easy way for distinguishing wetland from non-wetland areas within a certain location (e.g. protected area boundaries). It allows the presentation of statistics for multiple sites, based on land use/land cover information, previously extracted using the SWOS toolbox (Figure 3-2).

USER ENGAGEMENT & EXPERIENCE

The mapping results provide great potential for further spatial analysis and assessment, and for formulating important policy messages. Here, the production and dissemination of an e-publication (in pdf format) is envisaged by SWOS partner EKBY (Greek Biotope Wetland Centre) in collaboration with the Greek Ministry.

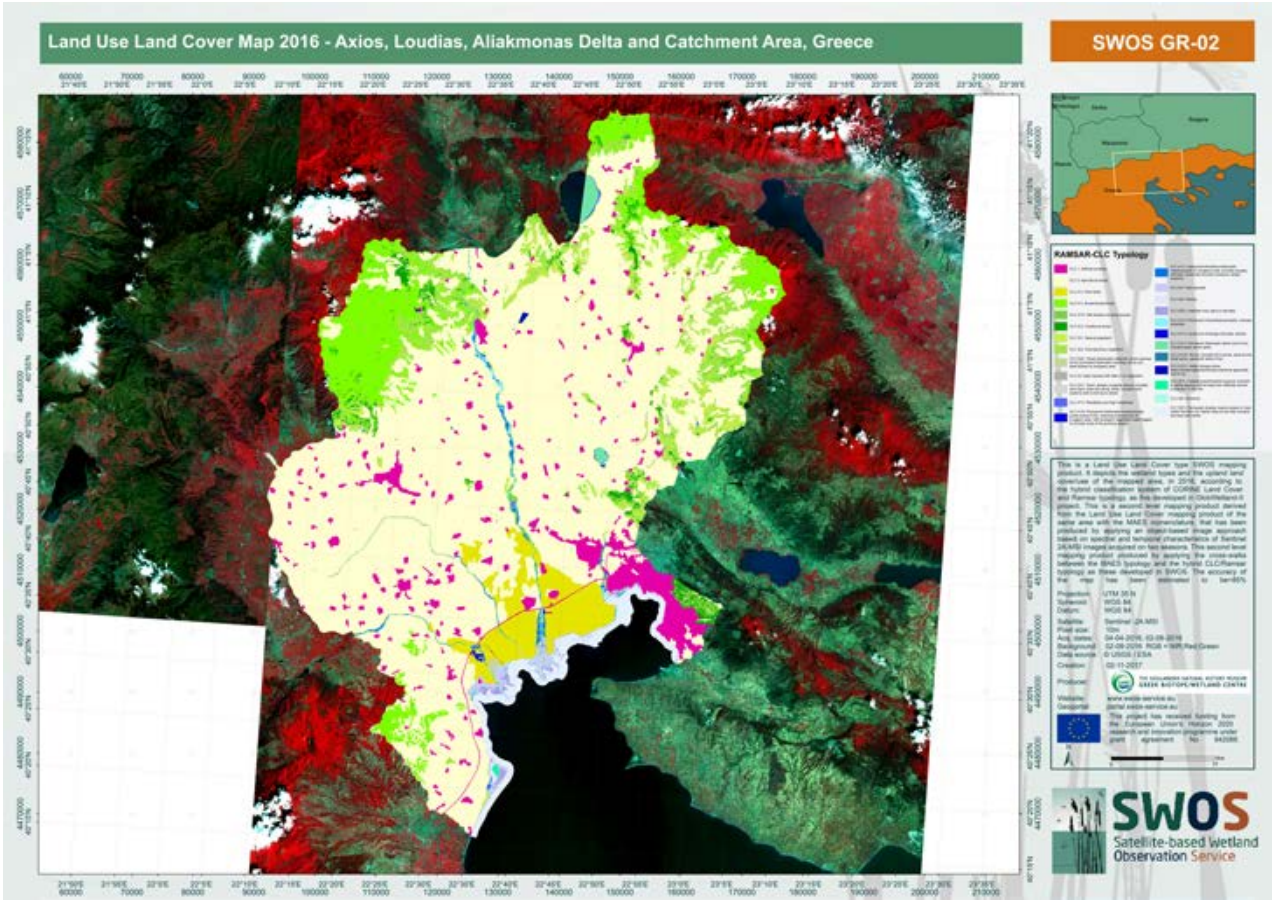


Figure 3-1. Example of a Land Use /Land Cover Map for 2016 (Source: Ekby, contains modified Copernicus Sentinel-2 data 2016).

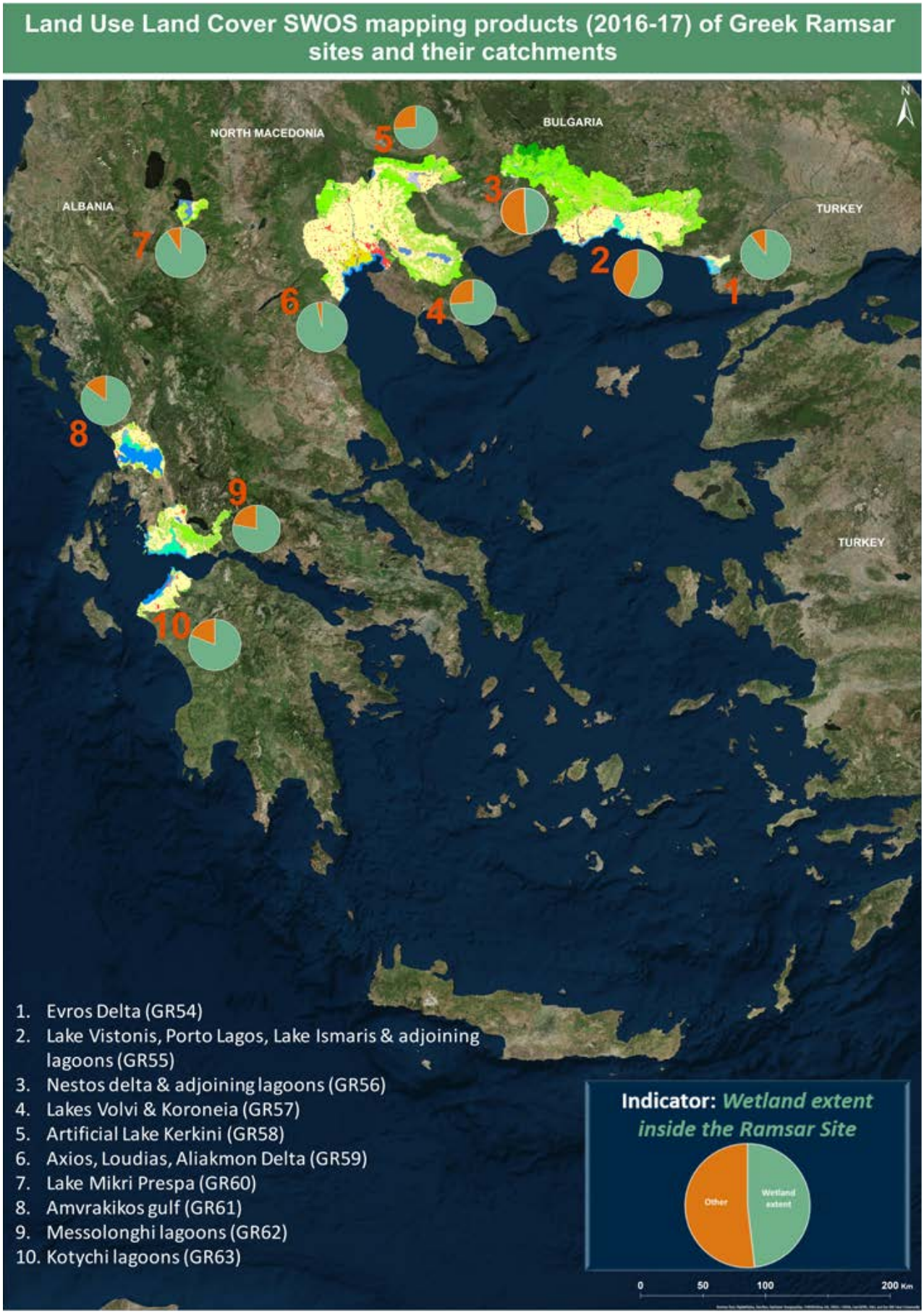


Figure 3-2. Total wetland ecosystem extent inside the 10 Greek Ramsar sites based on SWOS LULC maps for the years 2016-2017 (Source/Design: Ekby).

Service Case 2

Monitoring water quality of large water bodies in relation to LULC long-term dynamics – Berre and Bolmon lagoon (France)

OVERVIEW MAP

Berre and Bolmon lagoon (France)

TARGET POLICY

Safeguarding water quality is the main objective of the European Water Framework Directive (EU WFD), as well as being a global challenge. As such, it is included in the 2030 Agenda for Sustainable Development (SDG 6: *Ensure availability and sustainable management of water and sanitation for all*).

MAPPING PRODUCTS

Water Quality maps

Four crucial water quality products have been developed and refined in the context of SWOS. These are products exhibiting spatial and temporal variation in absolute or relative water quality parameters for: 1) chlorophyll-a (CHL); 2) Total Suspended Matter (TSM); 3) Colored Dissolved Organic Matter (CDOM); and, 4) Secchi depth. Based on MERIS/Sentinel-3 data, maps can be derived for wetlands with open water surfaces (> 3 km^2), where the water depth exceeds the Secchi depth. Using Landsat 8 or Sentinel-2 data, smaller water surfaces can be mapped.

SWOS INDICATOR

Water Quality Index

The SWOS project has developed a Water Quality Index based on remote sensing data. This enables estimates of four water quality parameters to be quantified: concentration of chlorophyll-a, concentration of suspended matter, absorption of coloured dissolved organic matter, and Secchi depth. Together these attributes provide comprehensive information on water quality. Moreover, the SWOS Water Quality Index, used in conjunction with land cover data over time, can allow the identification of pollution sources. Thus, these SWOS products can be used to provide information on water bodies' water quality in response to international demands (United Nations and European Union) and allow the long-term monitoring of water quality in more specific cases, such as Ramsar sites. The monitoring of chlorophyll-a concentration is possible using remote sensing and is applicable at large scales; for example, the Berre lagoon (15,500 ha). Using results from the SWOS water quality product allows the identification of algal blooms due to its correlation with chlorophyll-a concentrations in water. In Figure 3-4, during a period of 7 years, four algal blooms with chlorophyll-a concentrations exceeding 30 µg/l can be clearly identified in 2003, 2004, 2006 and 2009.

USER ENGAGEMENT & EXPERIENCE

Wetland and water resource managers are keen to have seamless and timely information on

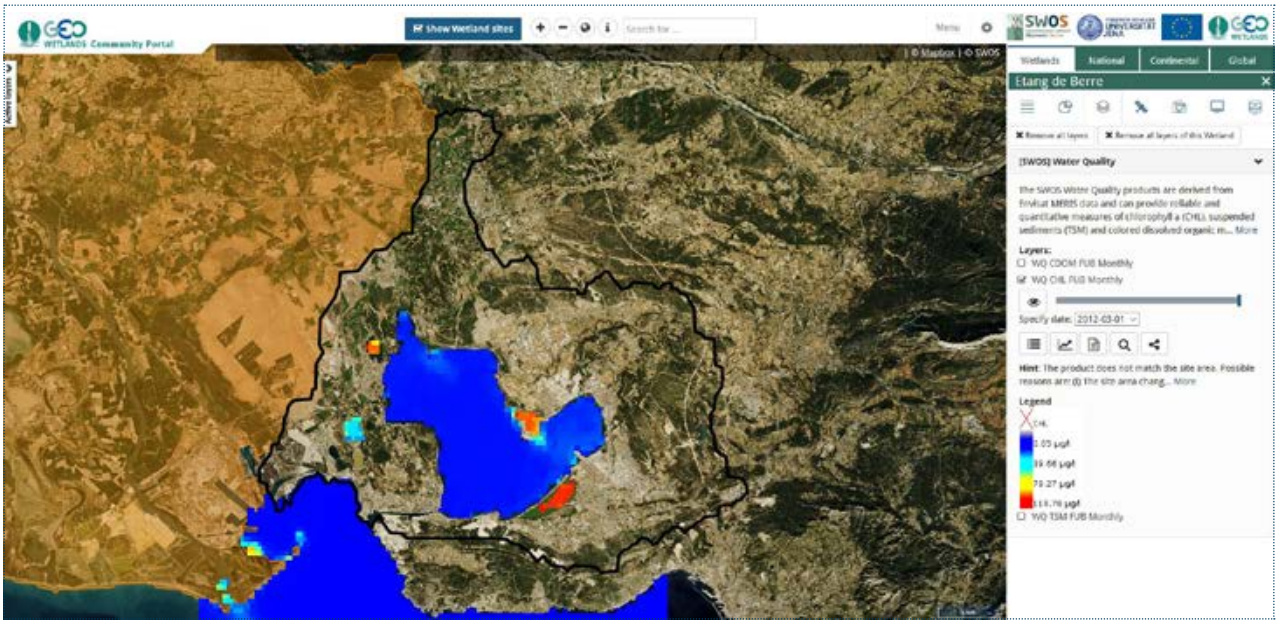


Figure 3-3. Water Quality map (chlorophyll-a) of Berre lagoon wetland site, France (Source: Brockmann Geomatics Sweden AB, visualization in the GEO-Wetlands Community Portal).

different aspects of water quality. The remote sensing-based Water Quality Index provides such a product, with a long time series and large spatial coverage (Figures 3-3 and 3-4). Both the pressure of surrounding activities (agriculture, industry, waste water plants) and the success of restoration measures regarding water quality, can be monitored. For instance in the Berre lagoon, significant programmes are ongoing to restore hydrology and biodiversity.

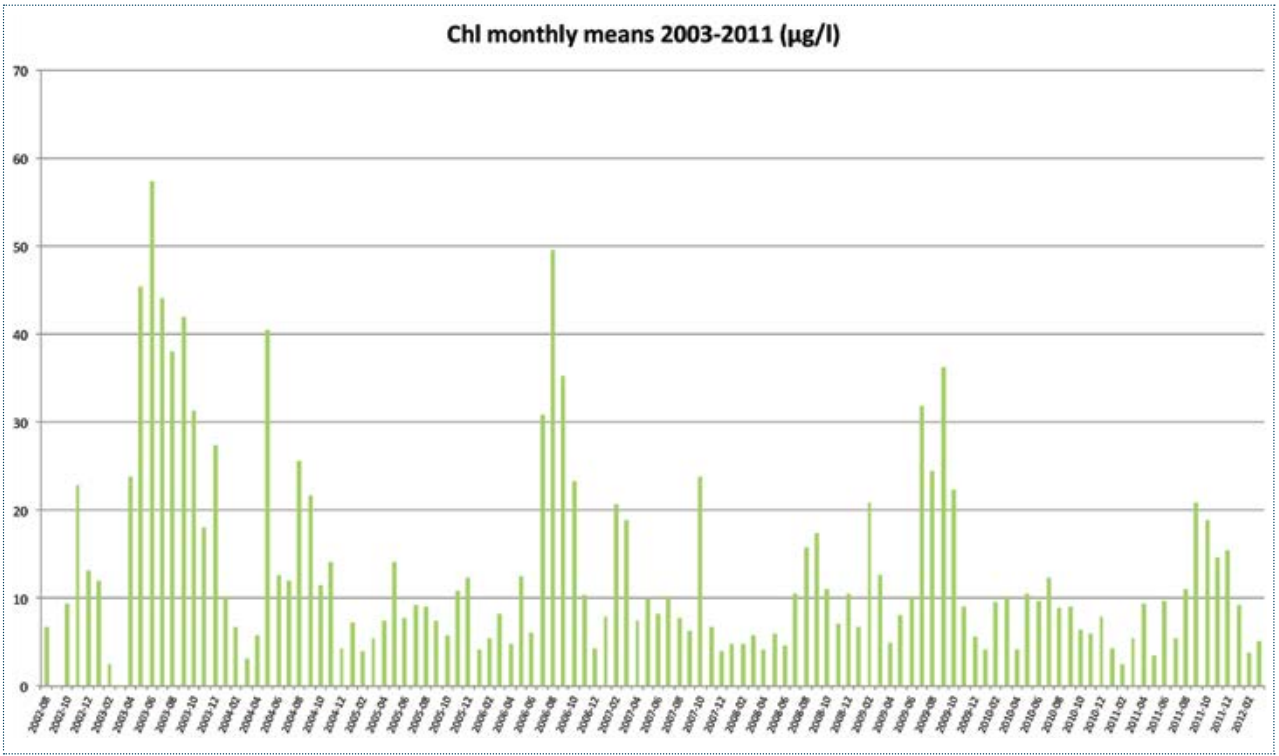


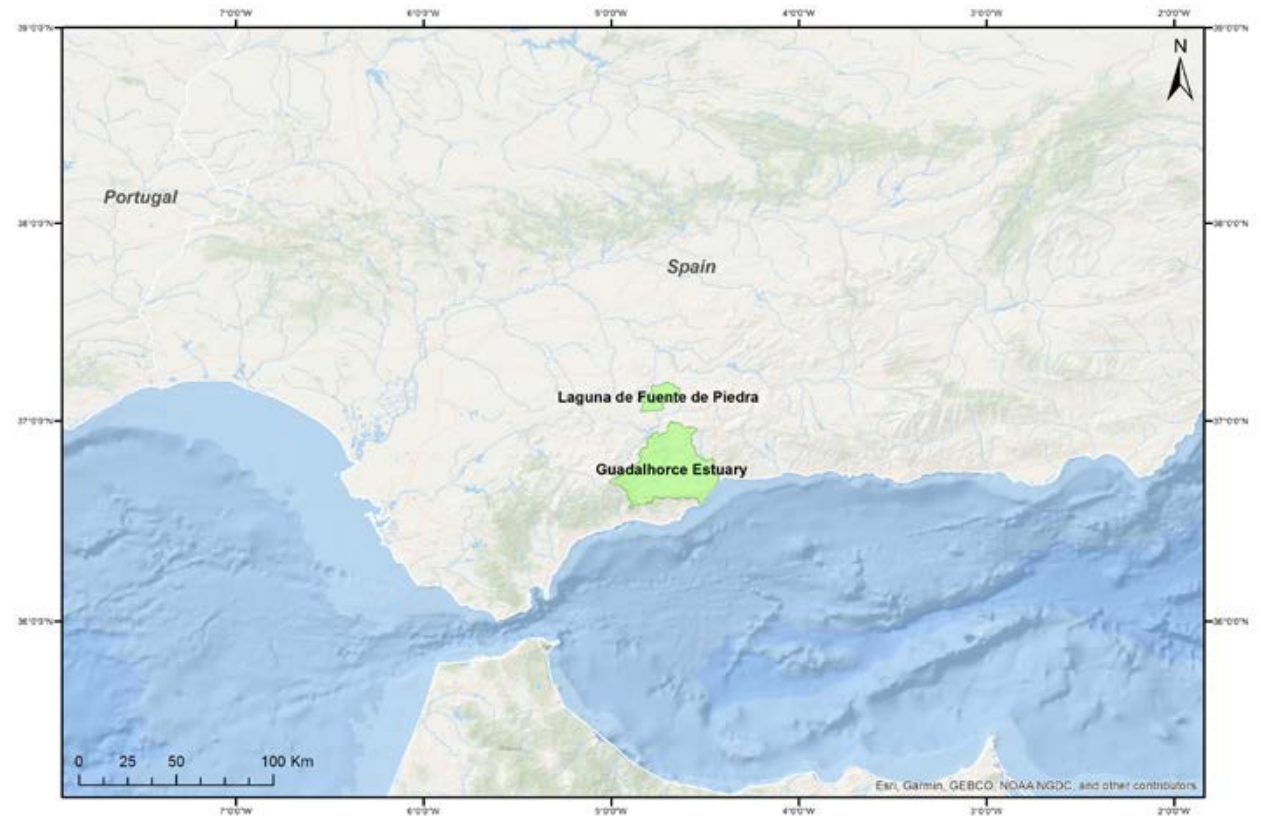
Figure 3-4. Monitoring of chlorophyll-a concentration using remote sensing in Berre lagoon between 2002 and 2012 (Source: Brockmann Geomatics Sweden AB).

Service Case 3

Wetland delimitation and restoration at Fuente de Piedra (Spain)

OVERVIEW MAP

Fuente de Piedra (Spain)



TARGET POLICY

Target 2 of the **EU Biodiversity Strategy** states that "*by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems*". In Spain, local and subnational wetland management already includes many restoration initiatives to improve the condition of Andalusian wetlands. These initiatives trigger the recovery of wetland ecosystems. By reducing pressure they allow natural processes and ecosystem functions to support the restoration of designated areas. At the local level, the **management plan of the protected area** establishes priority areas for restoration measures. The plan focuses on degraded and contaminated sites, as well as those affected by soil erosion, aiming at improving the ecological and landscape conditions, and ensuring restoration is based on the criteria of the Andalusian Wetland Plan.

OTHER RELEVANT POLICIES

Convention on Biological Diversity (Aichi Biodiversity Targets 5 and 8); UN SDG 6; EU Water Framework Directive; Regional Wetland Plan and Local Natura 2000 management plan.

MAPPING PRODUCTS

Wetland Delimitation

The wetland owes its water levels to precipitation, runoff and the underground water table of the endorheic hydrological basin in which it is located. The site limits used for mapping and assessment are based on the area of hydrologic processes (hydrological and hydrogeological basins) of Fuente de Piedra, combined with the administrative limits of the Natura 2000 site. This delimitation considers the hydro-ecological characteristics of the wetland. Hence, all mapping products cover the area of influence, allowing the identification of relevant pressures and threats within the overall extent of the wetland ecosystem (Figure 3-5).

SWOS INDICATOR

Wetland restoration

The Wetland restoration indicator provides information about areas converted from any land cover type to natural wetland. It helps to track the specific restoration-related changes and quantify them for different time periods. In this way, restoration activities can be monitored in terms of actual change of land cover between different points in time, which can be selected very flexibly, based on the large availability of satellite imagery from Sentinel 2. It therefore covers the needs both of local wetland managers that are overseeing the restoration activities, as well as regional agencies, European institutions, and global initiatives in charge of monitoring and assessing overall restoration efforts. The restoration of the entire lake area in the 1980's ensured the recovery of the wetland system. It has since become home to the largest colony of flamingos on the Iberian Peninsula and the second largest in Europe.

USER ENGAGEMENT & EXPERIENCE

Local wetland managers at the Natural Reserve suggested a comprehensive delimitation of the wetland. Surface Water Dynamics and Land Use/Land Cover mapping allow continuous and harmonised mapping of the whole area. The regional government of Andalusia is eager to adopt the SWOS tools for mapping and monitoring of all wetlands included in the Andalusian Wetland Inventory. This would provide them with harmonised information for a number of different indicators. Finally, the restoration indicator is a valuable tool to assess the degree of achievement of the restoration targets set by the CBD and the EU Biodiversity Strategy (Figure 3-6).

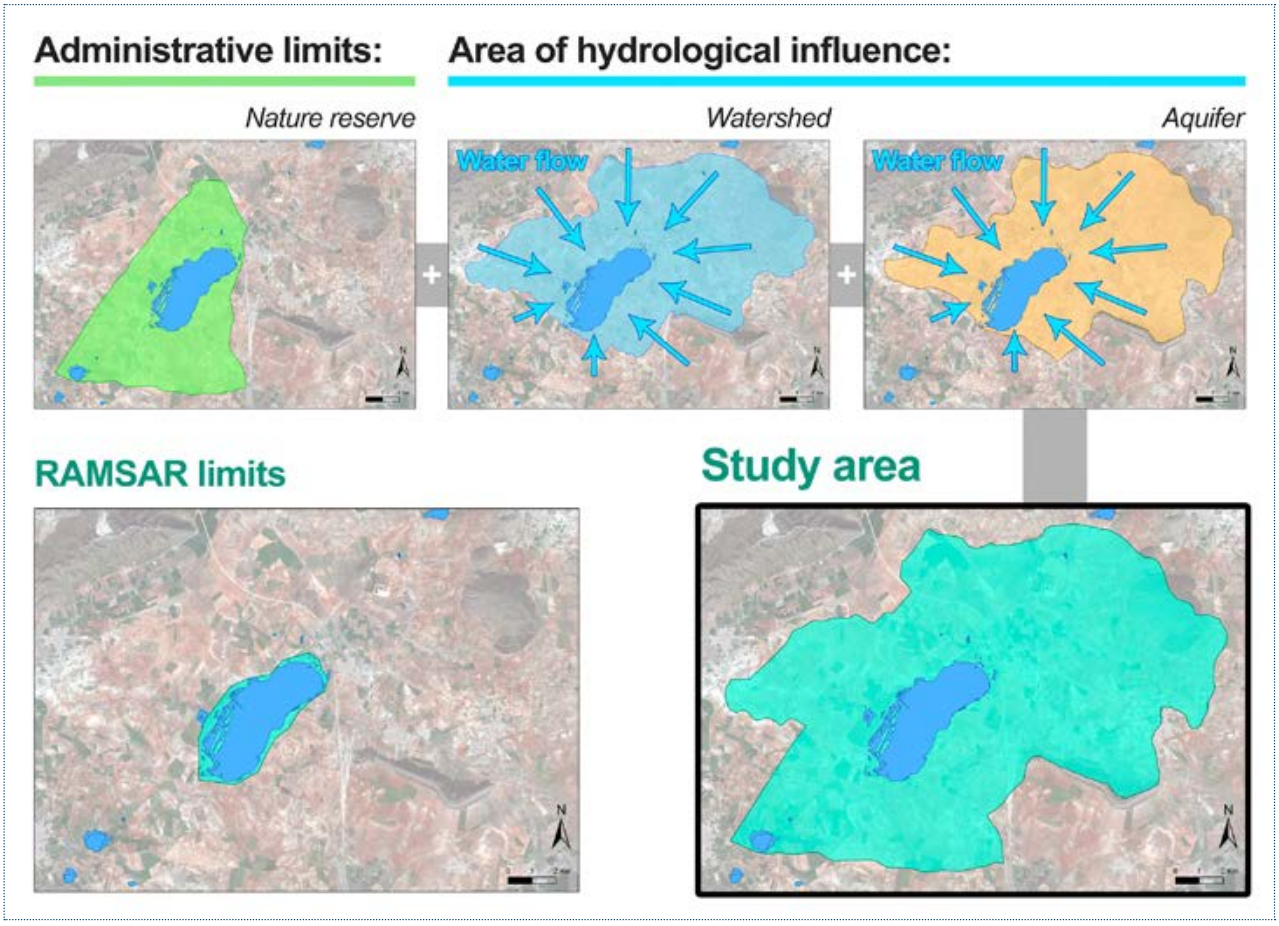


Figure 3-5. Components of the wetland ecosystem delimitation (Source/Design: ETC-UMA).

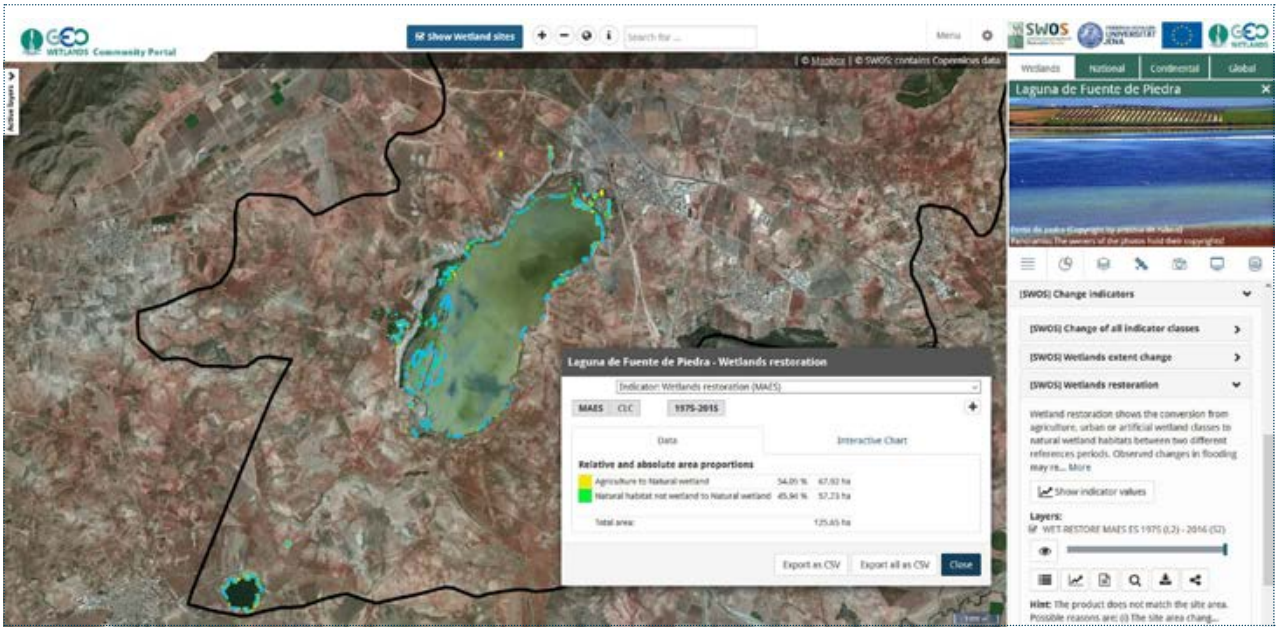


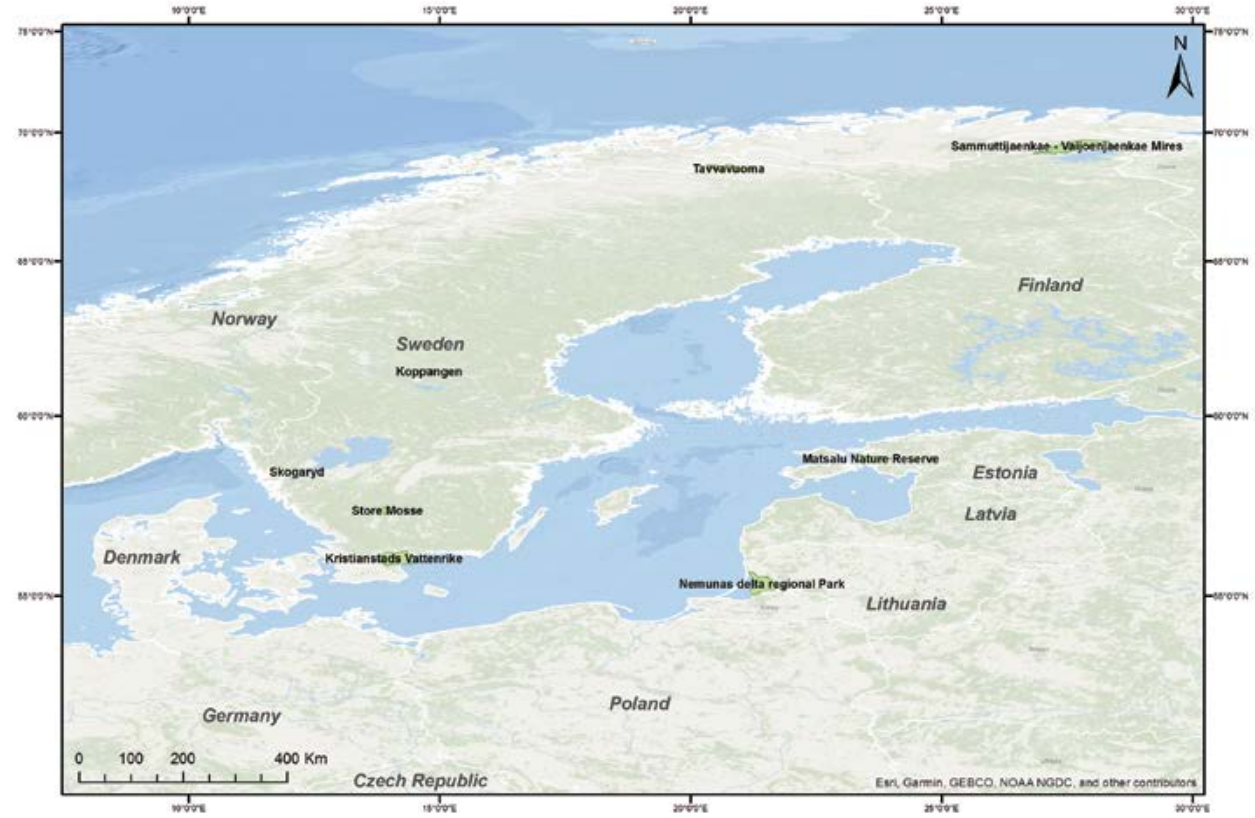
Figure 3-6. Wetlands restoration indicator for Laguna Fuente de Piedra (Source: ETC-UMA, contains modified Copernicus Sentinel-2 data 2015).

Service Case 4

Peatland mapping at Tavvavuoma, Store Mosse, Skogaryd (Sweden)

OVERVIEW MAP

Tavvavuoma, Store Mosse, Skogaryd (Sweden)



TARGET POLICY

The target policy of this Service Case is the EU Land Use, Land Use Change and Forestry (LULUCF). The EU has committed to achieve at least 40% domestic reduction in GHG emissions compared to 1990 levels, by 2030. The EU LULUCF proposal takes a land-based approach, thus streamlining the EU system with the UNFCCC

land-based reporting framework. As per Article 2 of the EU LULUCF proposal, Member States will be required to report on emissions and removals of GHGs from the different land accounting categories during the period from 2021 to 2030. This requires improved knowledge on peatland extent and status, and monitoring of changes (both positive and negative) due to several different factors. SWOS tools and products can help provide some of the required information to achieve this.

OTHER RELEVANT POLICIES

Several policies address GHG emission reporting for different land cover and land uses, including monitoring of peatland extent and status. They aim to improve the understanding of the extent of peatlands worldwide, the historical and current changes, as well as threats to peatlands and issues related to improving measures to reduce GHG emissions. In addition to the EU LULUCF, other relevant policies include the UNFCCC Paris Agreement, IPCC Guidelines, Ramsar convention, Global Peatlands Initiative, peatland restoration and climate mitigation actions post-2020.

MAPPING PRODUCTS

Tavvavuoma (Figure 3-7)

In Figure 3-7, two SWOS products are shown; a subset of LULC classes (open mires and peatlands), the Potential Wetland (modelled), and a combination of the two. A comparison of these two products can identify areas of change in peatland due to drainage, climate change (forest and shrub encroachment because of drier conditions) and the effects of restoration activities. Given the plan to maintain the ESA Sentinel missions in the foreseeable future, these products can also help provide a baseline for future monitoring of change.

Skogaryd (Figure 3-8)

GHG emissions vary with Land Cover and Land Use. The difference in nutrient content between peatlands based on fen peat and bog peat are quite large and the GHG emission values are different for both natural areas and drained areas. An area with both fen and bog peat, in the Skogaryd site is shown in two different satellite image versions: a) VHR Copernicus Core_003 Seamless Mosaic, and b) Sentinel-2. In c), the soil map is shown and depicts differences in peat type. This area has been drained and planted with spruce forest. The forest cover on the fen peat is dense and highly productive, whereas the forest cover on the bog peat is sparse with low productivity. When it comes to linking data on carbon storage capacity and GHG emissions with different land cover/land use, further division of the MAES class is needed (see c). Currently the MAES coniferous swamp forest class for both areas does not highlight this difference, but Sentinel-2 imagery (used in SWOS) has inherent spectral and

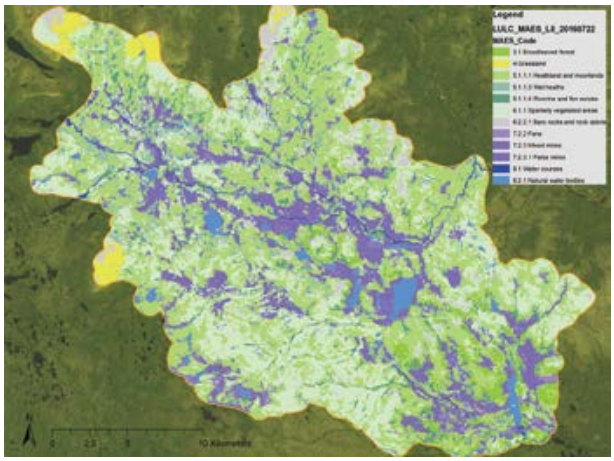
spatial capacity to differentiate them. Discussions with the Skogaryd users regarding the importance of this are ongoing.

Store Mosse (Figure 3-9)

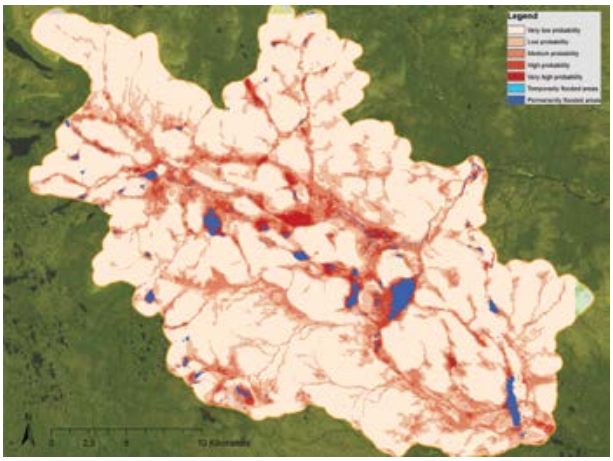
The figures below demonstrate the potential for high resolution satellite imagery (Sentinel-2 and Sentinel-1) and wetland mapping tools to monitor the success of mitigation operations (Figure 3-9). It is possible to a certain extent, to differentiate between former peat extraction areas (pink) and the natural bogs (blue) (Figure 3-9c). As the restoration areas return to a more natural state they should become more spectrally similar to the adjacent natural areas. Therefore, it may be possible in the future to use a time series of Sentinel-2 images to capture the nature and spatial extent of these changes for monitoring and management purposes.

USER ENGAGEMENT & EXPERIENCE

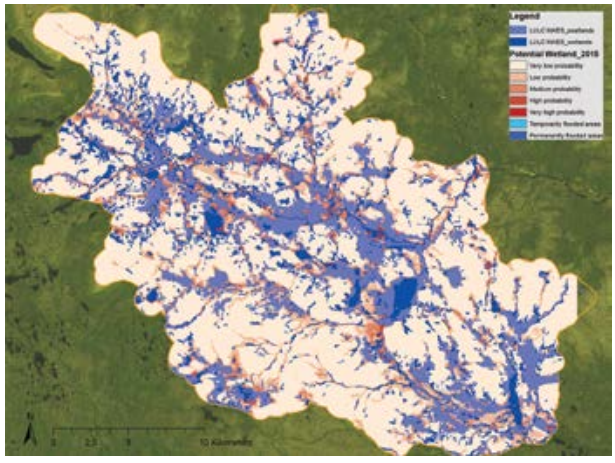
The users at the three sites in the peatland service case have all been engaged in discussions with SWOS partners, and have at different stages, reviewed satellite images and initial SWOS products. They have indicated that they see potential for these to contribute positively to their work; discussions are ongoing and the potential value of additional products, such as soil moisture, surface water dynamics, and Sentinel-1 intermediate products, as well as the use of the SWOS tools, will be further reviewed before the end of the project.



MAES LULC mapping Open mire classes grouped

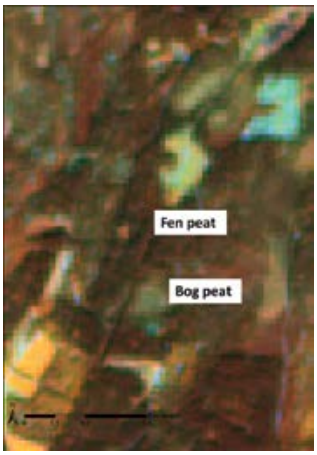


Potential Wetland layer

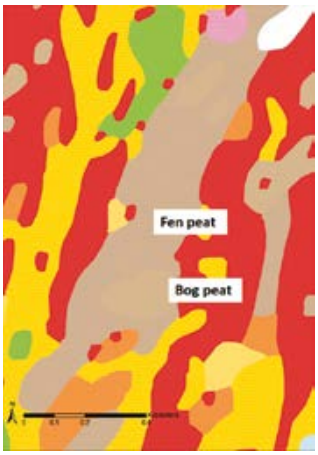


Potential Wetland with LULC mapped wetland classes (open mires)

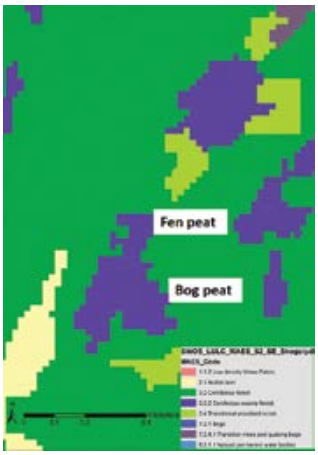
Figure 3-7. Combination of SWOS products derived from high resolution satellite data (Sentinel-2) and ancillary data such as DEM and watershed modelling for the SWOS site Tavvavuoma, Sweden (Brockmann Geomatics Sweden AB, contains modified Copernicus Sentinel-2 data 2016).



a) Sentinel-2 RGB (B8, B12, B4)



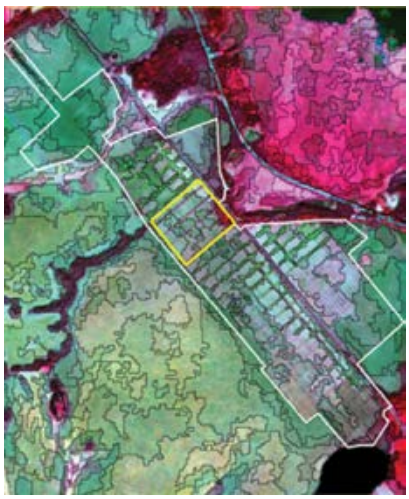
b) Soil map (wms Swedish Geological Survey)



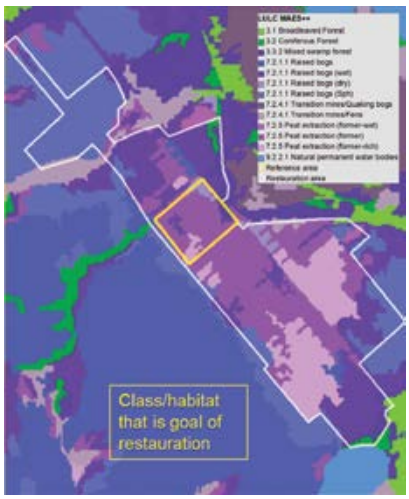
c) SWOS LULC MAES classification

Figure 3-8. Images and maps of the Skogaryd site highlighting two different forested peatland types (Brockmann Geomatics Sweden AB, contains modified Copernicus Sentinel-2 data 2016).

a) Sentinel-2 (2015-08-09, RGB, B8, B4, B3



b) S2-image segmentation and restoration area (white line), reference area not restored (yellow line)



c) LULC MAES image classification using SWOS tool with area that is the goal of restoration marked

Figure 3-9. Store Mosse restoration site Hädingetäkten (Brockmann Geomatics Sweden AB, contains modified Copernicus Sentinel-2 data 2015).

SWOS can be used as a tool to identify areas for restoration and conservation, e.g. by assessing ecosystem services and mapping wetland extent dynamics.

SWOS Methods for Wetland Restoration and Conservation: Achieving the No-Net-Loss Target

Degradation of the world's ecosystems, including wetlands, has immense negative impacts on biological diversity as well as on people's livelihoods. There is a growing realization that we will not be able to conserve the Earth's biological diversity through the protection of remaining areas of conservation importance. Restoration of degraded ecosystems thus has a critical role to play. Ecosystem restoration is the "*process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed*" (39).

The EU Biodiversity Strategy highlights in Target 2 the importance of maintaining and restoring ecosystems, with one of its goals being to restore 15% of degraded ecosystems by 2020. Action 7 is to "assess the impact of EU funds on biodiversity and investigate the opportunity of a compensation or offsetting scheme to ensure that there is no net loss of biodiversity and ecosystem services".

In this section, the SWOS partners present several monitoring and assessment methodologies which have been tailored to the information requirements of priority wetland conservation and restoration measures.

SWOS can be used as a tool to identify areas for restoration and conservation, e.g. by assessing ecosystem services and mapping wetland extent dynamics. In this way, SWOS supports the achievement of many EU biodiversity targets as referred to in the EU Biodiversity Strategy as well as meeting commitments to various global international agreements, including the Paris Agreement on climate change.

SWOS products and tools are presented to showcase how wetlands can be assessed in terms of their capacity to supply ecosystem services and how the tools/products can help in the identification of areas that:

a. are under threat of future degradation,
b. have high potential for restoration,
c. are priorities for conservation

Relevant policies are named for all examples and they are accompanied by short summaries of the methodology and results to provide an overview of their potential to support future policy developments.

Contributing to flood regulation

Floods are extremely hazardous to human societies, with impacts being frequently recorded in settlements around water bodies and flood plains. Artificialisation of the structure of water bodies and their catchment areas increase the risk of flooding. The capacity to regulate floods is a vital function of ecosystems, helping to mitigate the negative effects of water-related disasters.

The flood regulation indicator developed under SWOS supports the EU Directive 2007/60/EC on the assessment and management of flood risks (Flood Directive). The Flood Directive requires Member States in the European Union to assess flood risk along water courses and on coastlines, map this flood risk extent in relation to population size, and take adequate and coordinated measures to reduce this risk. The indicator can also prove useful in supporting the identification of important areas to contribute to international and European targets, such as the Sustainable Development Goals and the EU Biodiversity Strategy to 2020 (and the MAES working group focusing on Target 2 Action 5). This indicator would also contribute to meeting the objectives of the EU Water Framework Directive 2000/60/EC, namely, 'Towards better environmental options in flood risk management', especially in the wetland ecosystems that the EU WFD does not necessarily cover.

The indicator helps identify sites of accumulation of runoff and areas prone to high speed water flow in situations of high or torrential rainfall. Locating these sites can help stakeholders plan the mitigation of the impacts of extreme runoff, and identify areas for action to reduce the speed of floods generated by heavy rainfall, as well as areas for restoration to improve water infiltration and interception capacities. The approach has been developed at basin level. The methodology uses information on environmental parameters such as precipitation, slope, soil, vegetation cover, and land use/land cover to model water runoff generated by extreme precipitation events and to assess the capacity of the land to provide hydrological regulation. Society's demand for flood regulation provided by wetlands is assessed as the exposure and vulnerability of people and assets within flood-prone areas, taking into account the social and economic value of the assets exposed, human vulnerability and the spatial-temporal flood characteristics.

The results identify areas of high capacity to provide flood regulation. These should be interpreted as areas not to undergo human occupation but instead be protected and managed to maintain this ecosystem service and maximise its benefits (see Figure 4-1). Additionally, the maps help to detect areas with low service provision potential, where measures can be taken to improve it. With the help of the input data used for calculating the supply indicator, such as the percentage of rainfall transformed into runoff, it is possible to locate areas that contribute most to flooding. This information can be used to target restoration of certain ecosystems and application of nature-based solutions in the mitigation of floods. By combining the supply side (wetlands providing a certain level of flood regulation) with the demand side (the flood regulation capacity needed to protect human societies and assets), areas can be identified that are most affected by floods and where mitigation and evacuation plans should be focused. This combined mapping can be especially useful in agricultural and other semi-natural areas, to evaluate potential land use/land cover (LULC) changes that could increase the flood regulation capacity of the basin. For instance, the regions highlighted with red circles in Figure 4-1 correspond to upstream areas of the basin with low provision of the flood regulation service. These are areas of crops with little

Towards improving Flood Risk Management Plans

The methodology developed by SWOS assesses the capacity of wetland ecosystems to supply flood regulation services, as well as the existing demand of this service for society. This indicator is an evidence-based approach to understand the variables that contribute to the generation of floods and the socio-economic components that are most affected by them and their spatial location in the basin.

capacity to regulate runoff water, meaning they cannot fully satisfy the demand of the service which exists in downstream regions, and will contribute to increasing the magnitude of floods in lower parts of the basin. However, as seen above, these are areas that can potentially deliver high supply of this service if changes in LULC, restoration of natural vegetation or other mitigation measures are applied.

The methodology provides useful options for implementing the programmes of measures foreseen in flood risk management plans. It stresses the importance of nature-based solutions, such as Natural Water Retention Measures (NWRM, see also Section 2). Hence, the tool will continue supporting the improvement and integration of water-related and biodiversity policies beyond 2020.

SWOS methodologies are developed in line with the EU Biodiversity Strategy to 2020.

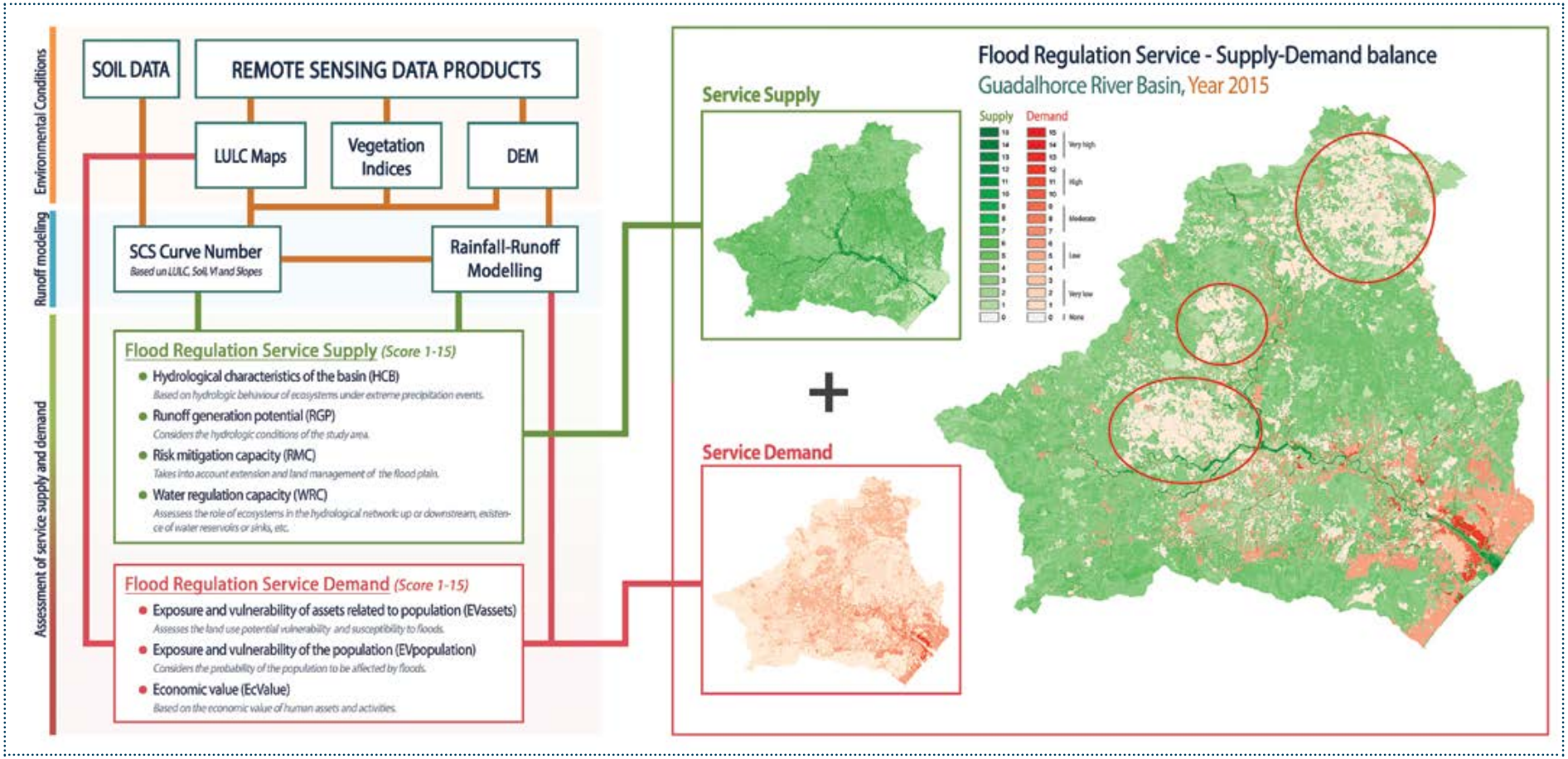


Figure 4-1. Methodology of the flood regulation service mapping and indicators (Source/Design: ETC-UMA, contains modified Copernicus Sentinel-2 data 2015).

“Habitat maintenance”: an ecosystem service supplied by wetlands

SWOS, as a Satellite Wetland Observation Service which focuses on mapping of wetland ecosystems and their services, pays particular attention to assessing the role of wetlands for “habitat maintenance”. “Habitat maintenance” refers to the service of ecosystems for supporting abundant and unique biodiversity. The SWOS toolbox is tailored to mapping and assessment of ecosystems’ extent and incorporates remote sensing techniques for land use/land cover (LULC) mapping and LULC changes (long- or short-term), wetland detection and delineation etc, following an ecosystem approach which implies holistic landscape assessments beyond the boundaries of protected areas.

In the service case “Assessment of wetlands’ role in “habitat maintenance”, in Attica Region of Greece (Figure 4-2), a SWOS methodological approach was developed in line with the EU Biodiversity Strategy to 2020 [2011/2307(INI)], which seeks to address the increasing deterioration of wetlands, among other important habitats. In particular, under the EU Habitats and Birds Directives, wetlands need to be addressed by urgent measures to improve their conservation status, as being of major importance for wild fauna and flora and hosting habitats and species of Community interest.

The conservation of biodiversity and ecosystem services needs to start at the local level. Small sized wetlands are often neglected due to the technical problems faced with mapping these wetlands, despite their recognizable importance for nature conservation. The assessment of wetlands’ role in “habitat maintenance” is applied at landscape level and is based on ecosystem maps adopting wetland detection EO techniques (see Figure 4-2). From ecosystem mapping the analysis moves to mapping of ecosystem condition by integrating biodiversity data that are reported by Member States under the EU Nature Directives. For mapping the supply and demand of habitats of good conservation status the strict protected areas and the Natura 2000 sites (N2K) are incorporated, considering the latter as the Service Benefit Areas (SBA).

This SWOS approach emphasised the important role of wetlands for securing the supply of the “habitat maintenance” service, averting

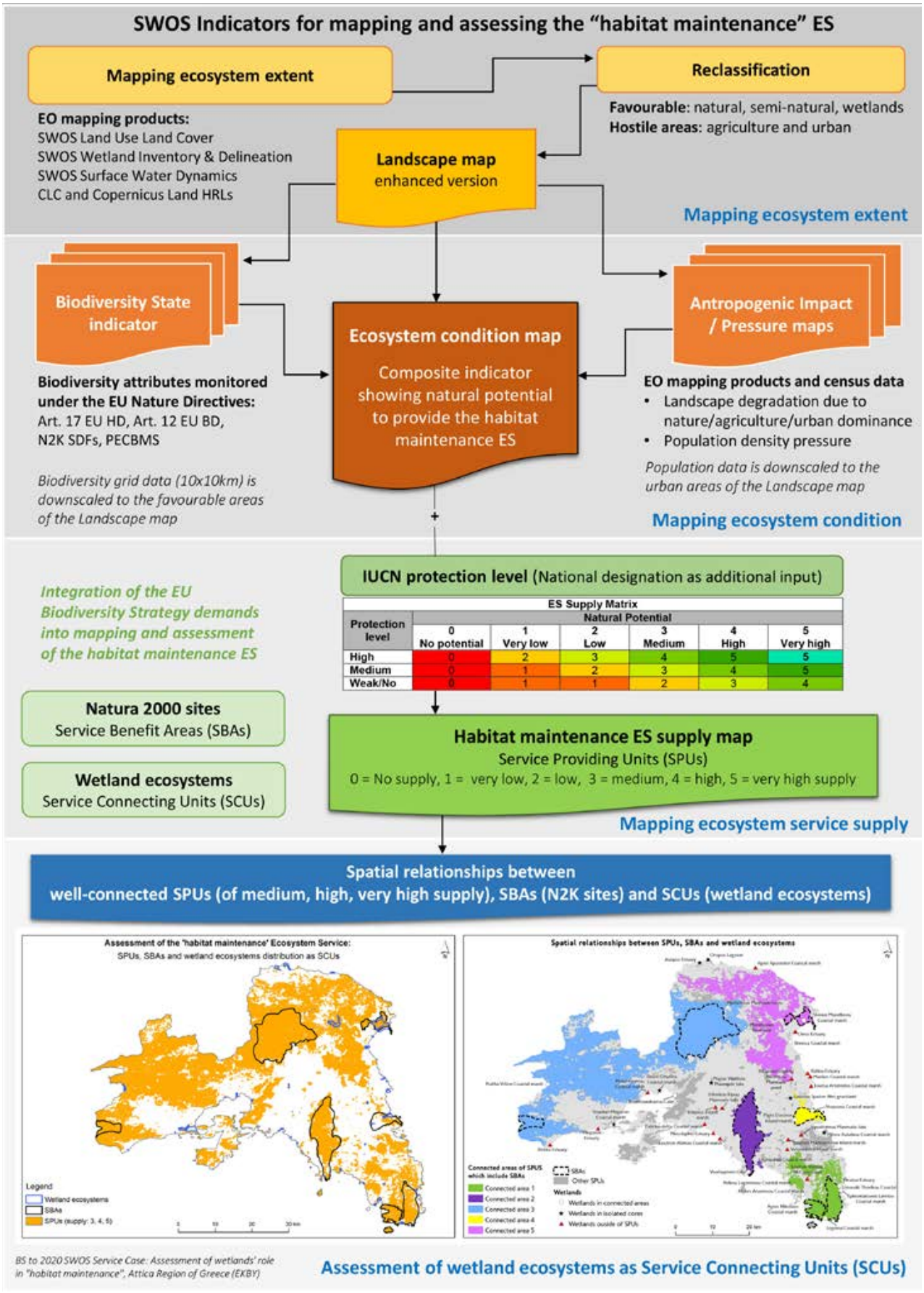


Figure 4-2. Methodology and results of habitat maintenance ecosystem service assessment (Source: EKBY, contains modified Copernicus Sentinel-2 data 2015).

biodiversity loss and preserving connected natural habitats at landscape level: habitats that are either part of connected Service Providing Units (SPUs) or stepping stones (isolated wetlands). A considerable number of wetlands that constitute Service Connecting Units (SCUs) were found in the landscape. These help to establish the role of Natura 2000 sites as Service Benefit Areas (SBAs) for the "habitat maintenance" ecosystem service supply. Furthermore, connectivity analysis indicated structurally connected areas that were crucial to the ecological and social resilience of the landscape.

Assessing the "habitat maintenance" role of wetlands should be part of regional landscape planning, to better conserve and restore wetlands and biodiversity. The landscape consists of patches of habitat within a matrix of surrounding land uses that are, to varying degrees, unsuitable for the present species. In this context, SWOS estimated the contribution of surrounding wetlands to the "habitat maintenance" ecosystem service supply and to the protected areas' connectivity. In other words, SWOS analysed the simultaneous potential of Natura 2000 sites to serve as SBAs, and wetlands to serve as SCUs. This perspective could be helpful for spatial planning and land management. It maps and assesses the wetlands which need to be conserved and restored for delivering a coherent Natura 2000 network.

Spatial prioritization tool for wetlands conservation and restoration

Given that wetlands are among the most threatened ecosystems in many countries, over the past few decades the implementation of wetland monitoring programmes has become an important priority for many national and international organizations. Wetland delineation is key to their management, but very few countries have a comprehensive inventory of their wetlands. This is partly due to a lack of tools that allow management authorities to efficiently undertake wetland inventories over large geographical areas.

The product and methodology of potential wetlands depict the location (inventory) and size (delineation) of potential wetlands in a particular geographical area (e.g. catchment area). Potential wetlands can be further classified into broad classes (e.g. coastal and near-shore marine wetlands, inland wetlands and man-made wetlands), using a combination of satellite imagery (Landsat time series, Sentinel-1 and Sentinel-2), topography, land use/land cover (LULC) and surface water dynamics maps, and ancillary data such as stream networks, soil maps and climatic models. The methodology allows the mapping of potential wetland areas with the definition of occurrence probability classes, in addition to two classes representing surface water seasonality (permanently and temporarily flooded areas). See

SDG 6 focuses on water resources and it aims to "achieve universal and equitable access to safe and affordable drinking water for all".

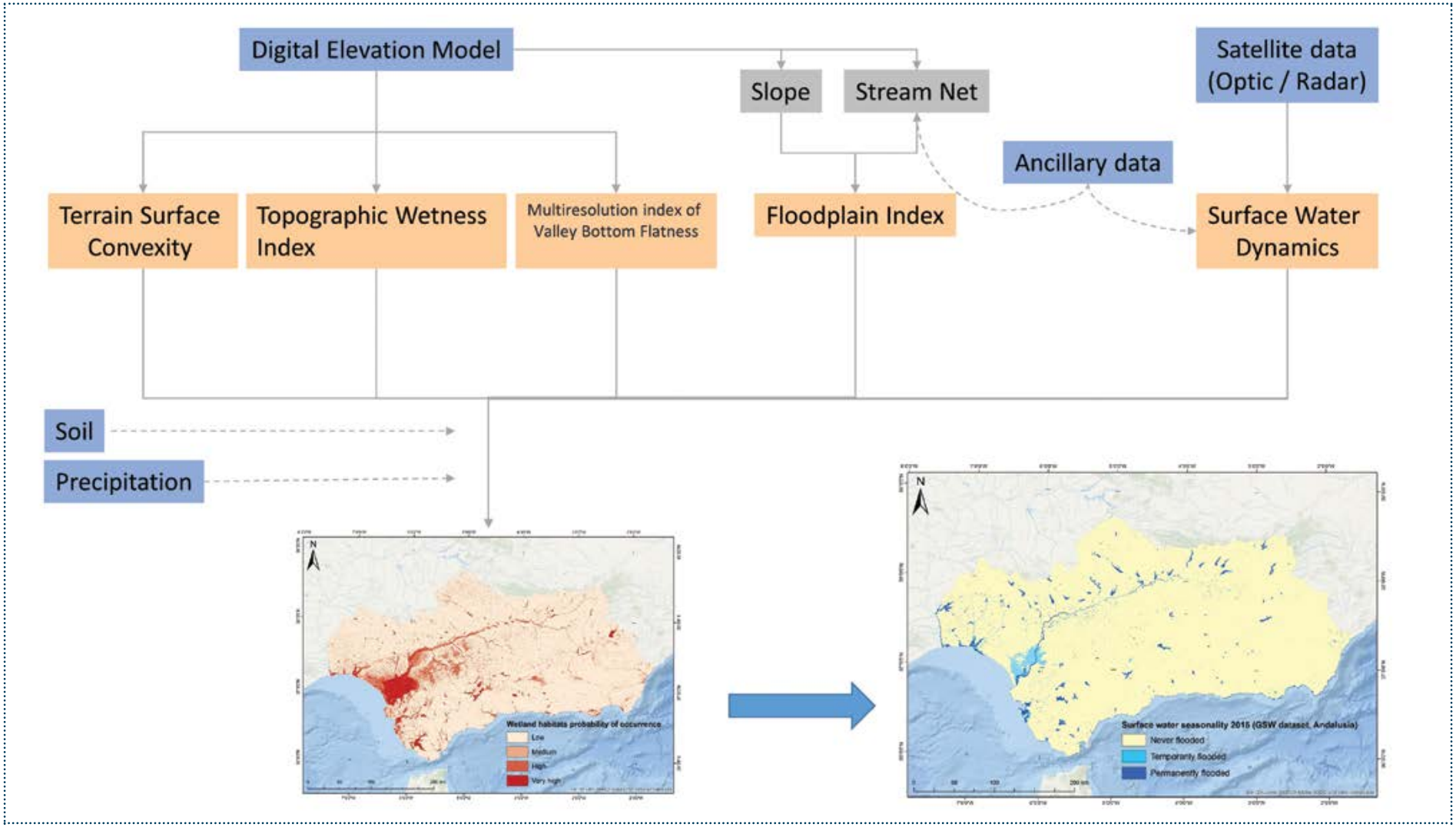


Figure 4-3. Workflow for extracting the potential wetland layer (ETC-UMA, Tour du Valat, contains modified Copernicus Sentinel-2 data 2015).

Figure 4-3 for more details about the input data and methodology.

This tool not only helps build regional or national inventories, but also supports restoration and conservation of wetland ecosystems by providing spatial information about the potential location of wetlands. Hence, if the potential location coincides with the actual presence of a wetland site, conservation measures can be put in place. If the area identified does not cover an existing wetland site, this area may be subject to restoration or transformation into a wetland, depending on the topographic and hydrological characteristics.

The Potential Wetland area product is especially valuable in less populated areas around the globe where the occurrence of wetlands is generally not well mapped. In addition, this cost-effective approach could be used as a supporting tool to help wetland conservation stakeholders in the implementation of comprehensive wetland inventories by combining both Earth Observation and in-situ data.

Quantifying Sustainable Development Goal Indicator 6.6.1 - change in the extent of water-related ecosystems over time

The Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development came into force on 1st January 2016. SDG 6 focuses on water resources and it aims to "*achieve universal and equitable access to safe and affordable drinking water for all*". It is a major step towards tackling water access issues and ensuring sustainable water management globally.

Sustainable and cost-effective forms of monitoring are essential to report on progress towards the targets of the SDGs. Monitoring systems are guided by SDG targets, which are supported by indicators and even sub-indicators, for which observations over time must be gathered. For SDG 6, indicators can help decision makers identify challenges and set priorities for water management. As seen earlier, Target 6.6 requires countries to "*protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes*". These ecosystems need to be adequately protected and where necessary restored because of their importance for the replenishment and purification of water resources and provision of ecosystem services. This target is currently to be monitored by Indicator 6.6.1: "change in extent of water-related ecosystems over time", requiring the setting of a wetland extent baseline and then measuring change from that baseline over time.

SWOS products can help provide the ecosystem extent data required to monitor Indicator 6.6.1. The current methodology for Indicator 6.6.1 is designated as Tier II, having been adapted and upgraded from Tier III in 2018. This means the indicator is conceptually clear, with internationally established methodology and standards. However, relevant data to support the indicator are not regularly produced by countries. The SWOS methodology is based on the mapping of wetlands and water-related ecosystems using satellite images (Landsat-8 in this case), combined with hydrological parameters derived from Digital Elevation Models (DEMs), according to the following steps: 1) potential wetlands mapping; 2) land use/land cover (LULC) and habitats mapping and 3) indicators computation.

The SWOS indicator for wetland extent uses the categories of water-related ecosystems according to the reporting requirements of an earlier version of the Indicator 6.6.1 methodology. This categorises wetlands into three classes: Vegetated Wetlands, Open Water Bodies and River Water Bodies. Figure 4-4 shows a demonstration of the methodology at national scale for the country of Albania. To meet the reporting requirements of the updated methodology developed by UN Environment, it would be necessary to separate out data on artificial water bodies. Nevertheless, by utilising satellite inter-annual time series, SWOS can support countries in their reporting obligations by providing information for the monitoring of SDG 6.6.1.

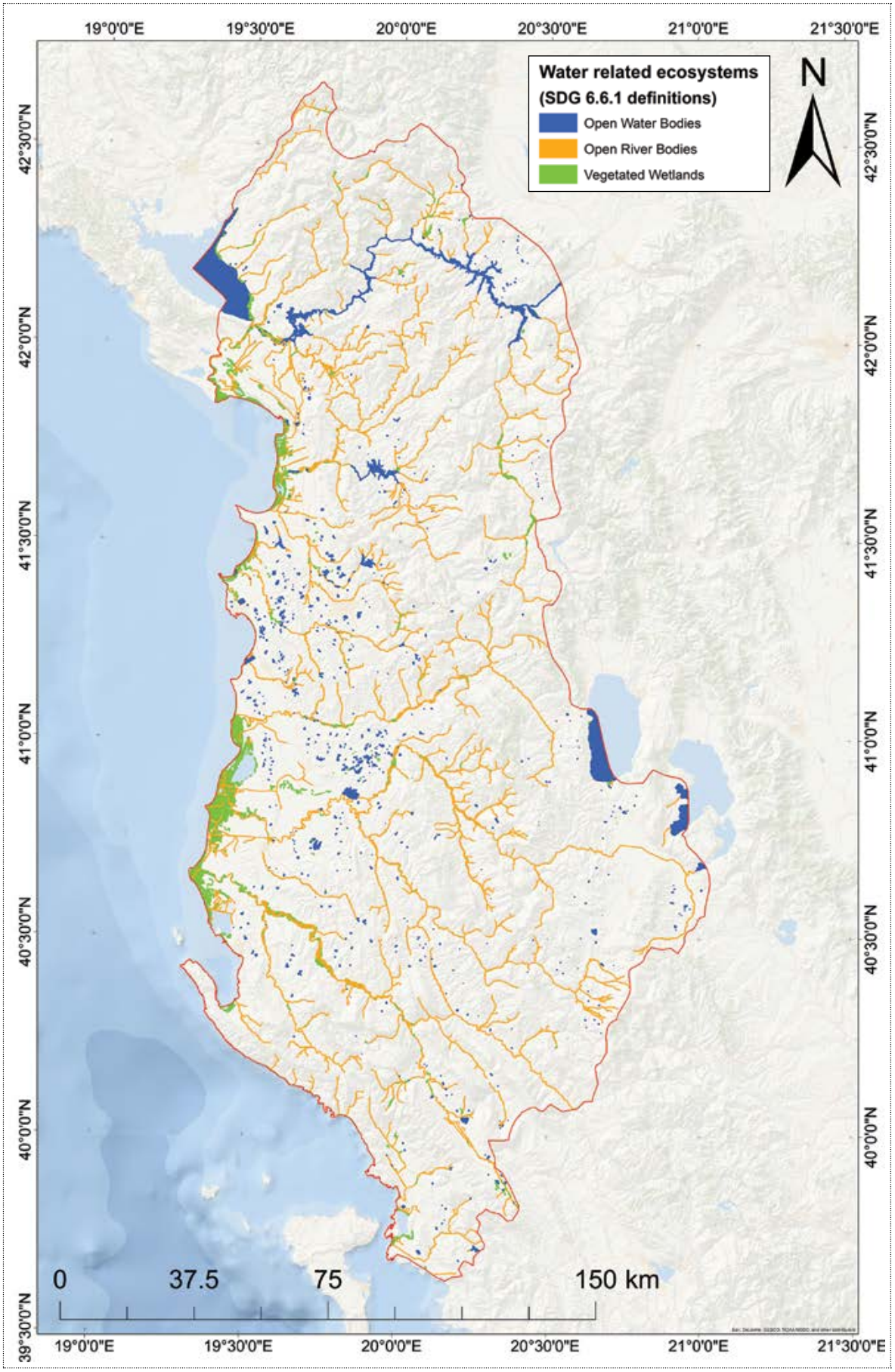


Figure 4-4. Water-related ecosystems in Albania mapped according to the SGD 6.6.1 definitions (Tour du Valat, contains modified Copernicus Sentinel-2 data 2015).

Conclusion

In order to reverse the global and European trend of water degradation, reliable baseline and monitoring information is required on wetland extent, condition and pressures. Furthermore, this information needs to be provided according to definitions consistent with the framing of global and European policies and targets on wetland conservation and restoration. The SWOS mapping products and indicators described in preceding chapters serve this aim and support reporting on national and global commitments on wetland conservation and restoration. A critical first step taken under the project was the expansion and harmonisation of the Mapping and Assessment of Ecosystem Services (MAES) ecosystem nomenclature, introducing new wetland classes where required. Crosswalks between these MAES classes, Ramsar types and CLC classes allow an unambiguous approach to reporting against multiple policy targets.

Beyond reporting on the extent of different wetland types, assessment of their condition is also essential and underpins Target 5 of the 2020 EU Biodiversity Strategy. The MAES indicator framework provides a comprehensive and consistent list of indicators of ecosystem condition, and SWOS indicators and map products serve the information needs for many of them. In chapter 3 we have seen these SWOS spatial knowledge products applied to:

- delineation of wetland (and non-wetland) habitats within Ramsar sites, as required under Article 2.1 of the Ramsar Convention
- water quality monitoring in support of the EU Water Framework Directive
- wetland delimitation in support of implementing the EU Biodiversity Strategy at the site level through management and restoration planning
- peatland mapping in support of GHG emissions modelling for the EU Land Use, Land Use Change and Forestry (LULUCF) package.

Such approaches are important in relation to the policy goal of Land Degradation Neutrality, or no-net-loss, as advanced by the EU Biodiversity Strategy 2020, UNCCD and SDGs. In Chapter 4 we see this demonstrated in relation to the spatial prioritisation of areas for conservation and restoration, flood regulation, habitat maintenance and in supporting the monitoring of SDG Indicator 6.6.1. SDG target 6.6, and other policies covered in this report, recognise that both humankind and biodiversity depend in many ways on healthy, functioning wetlands. Coordinated action is needed to ensure their favourable state. This will require the effective and joined-up implementation of wetland-related policies, supported by solid scientific evidence. This document reports on advances that have been made by the SWOS project to provide that scientific basis, and in so doing, identify opportunities to inter-link and strengthen policies for effective wetland protection.

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Annexes

ANNEX 1. Relationship between SWOS products and indicators in support of the MAES framework

ANNEX 2. Relationship between SWOS indicators and policy frameworks

Annex 1. Relationship between SWOS products and indicators in support of the MAES framework

PRESSURE INDICATORS				
Supported MAES Indicators (Maes et al. 2018)	**SWOS Indicators**	**SWOS Sub-indicators**	**SWOS Mapping products**	**Other required GI**
Pressure: Habitat conversion and degradation (land conversion)				
Change of area due to conversion (%/year) (SEBI 004) Land take (ha/year) (conversion from natural to artificial areas in floodplains or riparian areas) Ecosystem coverage change (%/year) (related to SEBI 004)	Wetland change to agriculture & urban	Natural and artificial wetland change into agriculture and urban Only natural wetland change into agriculture Only natural wetland change into urban Only artificial wetland change into agriculture Only artificial wetland change into urban Natural dryland change into agriculture Natural dryland change into urban Agriculture change in to urban Agriculture, urban and artificial wetland change into natural wetland	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Wetlands artificialisation	Change natural wetland into artificial wetland (including rice fields)	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Change in wetland area	Surface change for all wetland classes Surface change for natural wetland classes Surface change for artificial wetland classes Surface change for each wetland class or for a group of classes	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Anthropogenic Impact (CI)*	Landscape degradation (*pattern analysis with GuidosToolbox*) Population density*	Potential Wetlands Areas Surface Water Dynamics (SWD) Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	Population data per administrative unit

PRESSURE INDICATORS				
Supported MAES Indicators (Maes et al. 2018)	**SWOS Indicators**	**SWOS Sub-indicators**	**SWOS Mapping products**	**Other required GI**
Pressure: Climate change				
Climate impact & sensitivity (CI)	Change in wetland area	Surface change for all wetland classes Surface change for natural wetland classes Surface change for artificial wetland classes Surface change for each wetland class or for a group of classes	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Status of wetland threats	Agricultural areas by total area Urban area by total area All natural habitats that are not wetlands	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Status and Trend of Land Surface Temperature		Land Surface Temperature trend maps (LST)	
Pressure: Pollution and nutrient enrichment				
Exposure to eutrophication (mol nitrogen eq/ha/y)	Status and trend of water quality	Chlorophyll-a (concentration, µg l-1) Total Suspended Matter (concentration, mg l-1) Coloured Dissolved Organic Matter(absorption, m-1)	Water Quality (WQ)	In situ data
Pressure: Over-exploitation				
Agriculture intensity pressure on wetlands (CI)	Status of Wetland Threats	Agricultural areas by total area	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Status and Trend of Land Surface Temperature		Land Surface Temperature trend maps (LST)	

CONDITION INDICATORS				
MAES Indicators (*Maes et al. 2018; reference 24*)	SWOS Indicators	SWOS Sub-indicators	SWOS Mapping products	
Ecosystem attributes (biological quality of ecosystems): **Structural ecosystem attributes (general)**				
Landscape fragmentation (CI)	Ecosystem Fragmentation*	Number and mean size of natural habitat features (changes over time) Number and mean size of natural wetland features (changes over time) Number and mean size of natural dryland features (changes over time)	Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
Wetland connectivity indicator (<10 km from other wetland / >10 km from other wetland)	Wetland connectivity indicator* (<10 km from other wetland / >10 km from other wetland)		Potential Wetlands Areas Surface Water Dynamics (SWD) Land Use Land Cover (LULC)	
Threatened wetland-related habitats (%, number, area)			Land Use/Land Cover (LULC)	
Other	Extent of Open Water	Wetland habitats with permanent open water Wetland habitats with temporary open water Wetland habitats never flooded Flooded areas not wetland habitats	Surface Water Dynamics (SWD) Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC)	
	Total wetlands extent	Natural and artificial areas Only natural wetland areas Only artificial wetland areas Selected classes area		
	Change in wetland area	Change from agriculture or urban or artificial wetland classes to natural wetland habitats (wetland restoration)		
Ecosystem attributes (biological quality of ecosystems): **Structural ecosystem attributes monitored under the EU Nature directives and structural ecosystem attributes based on species diversity and abundance**				
Percentage of wetlands covered by Natura 2000 (%) Percentage of wetlands covered by National Designated Areas (%)	Total wetlands extent	Natural and artificial areas Only natural wetland areas Only artificial wetland areas Selected classes area	Potential Wetland Areas Land Use/Land Cover (LULC) Surface Water Dynamics (SWD)	

CONDITION INDICATORS				
MAES Indicators (*Maes et al. 2018; reference 24*)	SWOS Indicators	SWOS Sub-indicators	SWOS Mapping products	
Conservation status & trends of habitats of Community interest associated to wetlands (%) Conservation status & trends of species of Community interest associated to wetlands (%) EU Population status & trends of bird species associated to wetlands (%) Farmland Bird Indicator (index) (SEBI 001) (AEI2.4.1)	Biodiversity State	Habitats Condition Species Condition Population trends of breeding birds Habitat Richness Species Richness Habitat Distribution pattern Species Distribution pattern Amount of common farmland bird species	Potential Wetland Areas Land Use/Land Cover (LULC) Long-term Land Use/Land Cover Changes (LULCC) *to be used for downscaling EU Biodiversity datasets*	Conservation status and distribution of habitats and species (Article 17) Population trends and distribution of breeding birds (Article 12) Conservation degree (N2K SDFs) Lists of common farmland birds (PECBMS)
Ecosystem attributes (biological quality of ecosystems): **Structural soil attributes**				
Soil moisture (%)			Surface Soil Moisture (SSM)	

Annex 2. Relationship between SWOS indicators and policy frameworks

Policy/Agreement	SWOS Indicators												
	PRESSURE INDICATORS						CONDITION INDICATORS						
	Wetland change to Agriculture & Urban	Wetlands artificialisation and degradation	Change in wetland area	Status of Wetland Threats	Anthropogenic Impact	Status and Trend of Water Quality	Ecosystem Fragmentation	Wetland connectivity	Extent of Open Water	Total wetlands extent	Change to natural wetland area (from agriculture, urban or artificial)	Soil Moisture	Biodiversity State
UNDP Sustainable Development (SDGs 6 and 15 relevant indicators)													
6.3.2 Proportion of bodies of water with good ambient water quality	●	●	●	●	●	●	●	●	●	●	●	●	●
6.6.1 Change in the extent of water-related ecosystems over time	●	●	●	●	●	●	●	●	●	●	●	●	●
15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type	●	●	●	●	●	●	●	●	●	●	●	●	●
15.3.1 Proportion of land that is degraded over total land area	●	●	●	●	●	●	●	●	●	●	●	●	●
Convention on Biological Diversity (Aichi Biodiversity Targets 5 and 8 relevant indicators)													
Change in the extent of water-related ecosystems over time (Target 5)	●	●	●	●	●	●	●	●	●	●	●	●	●
Natural habitat extent (land area minus urban and agriculture) (Target 5)	●	●	●	●	●	●	●	●	●	●	●	●	●

● Low relevance ● Moderate relevance ● High relevance

Policy/Agreement	SWOS Indicators												
	PRESSURE INDICATORS						CONDITION INDICATORS						
	Wetland change to Agriculture & Urban	Wetlands artificialisation and degradation	Change in wetland area	Status of Wetland Threats	Anthropogenic Impact	Status and Trend of Water Quality	Ecosystem Fragmentation	Wetland connectivity	Extent of Open Water	Total wetlands extent	Change to natural wetland area (from agriculture, urban or artificial)	Soil Moisture	Biodiversity State
Wetland extent (Target 5)	●	●	●	○	○	○	●	○	●	●	●	●	○
Trends in fragmentation of forest and other natural habitats (Target 5)	●	●	●	●	●	○	●	●	○	○	○	○	○
Proportion of land that is degraded over total land area (Target 5)	●	●	●	●	●	●	●	●	●	●	○	○	○
Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density (Target 6)	○	○	○	○	○	●	○	○	○	○	○	○	○
Water Quality Index for Biodiversity (Target 6)	○	○	○	○	○	●	○	○	○	○	○	○	○
Proportion of bodies of water with good ambient water quality (Target 6)	○	○	○	○	○	●	○	○	●	●	○	○	○
Ramsar Convention													
A(i) Status and trends in wetland ecosystem extent	●	●	●	○	○	○	○	○	●	●	●	●	○
A(ii) Trends in conservation status – qualitative assessment	●	●	●	○	○	○	●	●	●	●	●	●	●

○ Low relevance ● Moderate relevance ● High relevance

Policy/Agreement	SWOS Indicators												
	PRESSURE INDICATORS						CONDITION INDICATORS						
	Wetland change to Agriculture & Urban	Wetlands artificialisation and degradation	Change in wetland area	Status of Wetland Threats	Anthropogenic Impact	Status and Trend of Water Quality	Ecosystem Fragmentation	Wetland connectivity	Extent of Open Water	Total wetlands extent	Change to natural wetland area (from agriculture, urban or artificial)	Soil Moisture	Biodiversity State
B(i) Trends in the status of Ramsar site ecological character – qualitative assessment	●	●	●	●	●	●	●	●	●	●	●	●	●
D(i) The frequency of threats affecting Ramsar sites – qualitative assessment	●	●	●	●	●	●	●	●	●	●	●	●	●
H(i) Coverage of the wetland resource by designated Ramsar sites	●	●	●	●	●	●	●	●	●	●	●	●	●
UNCCD (Strategic Action Plan 2018-2030)													
National Land Degradation Neutrality (LDN)	●	●	●	●	●	●	●	●	●	●	●	●	●
Sendai Framework for Disaster Risk Reduction													
Mapping and management of rivers, coastal flood plain areas, drylands, wetlands	●	●	●	●	●	●	●	●	●	●	●	●	●
EU Biodiversity Strategy (SEBI Indicators)													
SEBI 004 Ecosystem coverage	●	●	●	●	●	●	●	●	●	●	●	●	●

● Low relevance ● Moderate relevance ● High relevance

Policy/Agreement	SWOS Indicators												
	PRESSURE INDICATORS						CONDITION INDICATORS						
	Wetland change to Agriculture & Urban	Wetlands artificialisation and degradation	Change in wetland area	Status of Wetland Threats	Anthropogenic Impact	Status and Trend of Water Quality	Ecosystem Fragmentation	Wetland connectivity	Extent of Open Water	Total wetlands extent	Change to natural wetland area (from agriculture, urban or artificial)	Soil Moisture	Biodiversity State
SEBI 005 Habitats of European interest	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High
SEBI 013 Fragmentation of natural and semi-natural areas	Moderate	Moderate	Moderate	Moderate	Moderate	Low	High	High	Low	Low	Moderate	Low	Low
SEBI 016 Freshwater quality	Low	Low	Low	Low	Low	High	Low	Low	Low	Low	Low	Low	Low
SEBI 020 Agriculture: area under management practices potentially supporting biodiversity	Low	Low	Low	Low	Low	Low	Low	Low	High	High	Low	Low	Low
SEBI 023 Ecological Footprint of European countries	Low	Low	Low	Low	Low	Low	Low	Low	High	High	Low	Low	Low
Target 2: maintaining and restoring ecosystems and their services	Moderate	Moderate	High	Moderate	High	Moderate	High	High	High	High	High	Moderate	High
EU Water Framework Directive													
Good ecological status	Moderate	Moderate	Low	Low	Low	High	Moderate	Low	Low	Low	Low	Low	Moderate

Low relevance Moderate relevance High relevance

Policy/Agreement	SWOS Indicators												
	PRESSURE INDICATORS						CONDITION INDICATORS						
	Wetland change to Agriculture & Urban	Wetlands artificialisation and degradation	Change in wetland area	Status of Wetland Threats	Anthropogenic Impact	Status and Trend of Water Quality	Ecosystem Fragmentation	Wetland connectivity	Extent of Open Water	Total wetlands extent	Change to natural wetland area (from agriculture, urban or artificial)	Soil Moisture	Biodiversity State
Review of the environmental impact of human activity	●	●	○	●	●	○	●	●	○	○	○	○	○
Mitigating the effects of floods and droughts	●	●	●	●	●	○	●	●	●	●	●	●	○
Land Use, Land Use Change and Forestry (LULUCF) package under the EU Climate and Energy Framework													
Afforested land (including wetlands converted to forest land)	○	●	●	○	○	○	●	○	●	●	○	○	○
Deforested land (including forest land converted to wetlands)	○	○	●	○	○	○	○	○	●	●	●	○	○
Managed cropland (including wetlands converted to cropland and cropland converted to wetland)	●	○	●	●	○	○	●	●	●	●	●	●	○
Managed grassland (including wetlands converted to grassland and grassland converted to wetlands)	●	○	●	●	○	○	●	●	●	●	●	●	○
European Strategy for Green Infrastructure													
Wetland extent outside protected areas (indicator suggested by SWOS)	●	●	●	○	○	○	●	○	●	●	●	●	○

○ Low relevance ● Moderate relevance ● High relevance

Acronyms and Abbreviations

CBD: Convention of Biological Diversity

CLC: Corine Land Cover

CMS: Convention on Migratory Species

COP: Conference of the Parties

EC: European Commission

EEA: European Environmental Agency

EIA: Environmental Impact Assessment

ENVISAT: Environmental Satellite

EO: Earth Observation

ERS: European Remote Sensing

ESA: European Space Agency

EUNIS: European Nature Information System

FAO: Food and Agriculture Organisation

FRMPs: Flood Risk Management Plans

GHGs: Green House Gases

IPCC: Intergovernmental Panel on Climate Change

IUCN: International Union for Conservation of Nature

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

LDN: Land Degradation Neutrality

LULC: Land Use/Land Cover

LST: Land Surface Temperature

LULCC: Land Use/Land Cover Change

LULUCF: Land Use, Land Use Change and Forestry

MAES: Mapping and Assessment of Ecosystems and their Services

MEAs: Multilateral Environmental Agreements
MERIS: Medium Resolution Imaging Spectrometer

NGOs: Non-governmental organizations

NWRM: Natural Water Retention Measures

RBMPs: River Basin Management Plans

REDD+: Reduce Emissions from Deforestation and Forest Degradation

RGB: Red Green Blue

SAR: Synthetic Aperture Radar

SBA: Service Benefit Areas

SCU: Service Connecting Units

SDAGE: Senegal basin Wetland management policy

SDG: Sustainable Development Goal

SPU: Service Providing Units

SSM: Surface Soil Moisture

SWD: Surface Water Dynamics

SWOS: Satellite-based Wetland Observation Service

UN: United Nations

UNCCD: The UN Convention to Combat Desertification

UNFCCC: The UN Framework Convention on Climate Change

USGS: U.S. Geological Survey

WFD: Water Framework Directive

VHR: Very High Resolution

Partners

Jena-Optronik GmbH

University of Malaga

United Nations Environment Programme World Conservation Monitoring Centre

TerraSphere Imaging & GIS b.v.

Remote Sensing Solutions GmbH

Brockmann Geomatics Sweden AB

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SWOS
Satellite-based Wetland
Observation Service