SWOS Achievements, Innovations and Vision

November 2018

SWOS
Satellite-based Wetland Observation Service

Waddensea Netherlands, Sentinel 2, 2018-08-06
© contains modified Sentinel 2 Data 2018

SHORT SUMMARY

The Satellite-based Wetland Observation Service (SWOS) project generates information on wetland ecosystems using the possibilities offered by free satellite data. The most important objective of the SWOS project has been to provide a user-friendly wetland monitoring and information service, that is developed with and for the users. This report gives an overview of the main achievements of the SWOS project between 2015 and 2018 and looks at future opportunities for continuing the SWOS service for satellite-based wetland monitoring to users.

» Table of Content

1. What is the Satellite-based Wetlands Observation Service?

Wetlands are critical for human health and well-being and are hotspots of biodiversity. They are also one of the fastest declining ecosystems worldwide. The threats against them continue to mount. An increase in the conversion of natural areas to urban and agricultural areas, infrastructure development, water diversion and pollution of air and water are some of the main factors causing their degradation and loss.

Information on the location of wetlands, their ecological character and the services they give people (such as water sources, sources of food, storage of carbon and buffering or mitigating disaster risks) is often sparse and difficult to find or access. The result is a limited coverage of wetlands in policies and management practices.

The **Satellite-based Wetland Observation Service (SWOS)** project fills the information gap, which is hindering adequate management and protection of wetlands. SWOS generates information on wetland ecosystems using the opportunities offered by freely available satellite data. The SWOS Toolbox GEOclassifier and the SWOS / GEO-wetlands Community Portal provides wetland managers, policy-makers and scientists with access and tools to map the ecological character of wetlands and prepare indicators of wetland condition and changes.

The SWOS project is a European Union funded project under the Horizon 2020 Framework Programme for Research and Innovation. The unique partnership of users, universities and industry represents organisations specialized in developing, testing and validating innovative techniques and methodologies as well as user organisations involved in wetland conservation to ensure the final SWOS Services meet the needs of end-users.

The most important objective of the SWOS project has been to provide a user-friendly wetland monitoring and information service that is developed with and for users. With an innovative approach, SWOS supplies stakeholders with harmonized wetland information that supports management and reporting for environmental policies in different regions and at different scales. The service demonstrates opportunities for improved wetland management, planning and decision making, promoting the integration of wetlands across key policy areas.

In the coming years, SWOS aims to continue providing a service for satellite-based wetland monitoring to users. After the current project lifetime, SWOS will continue to offer the software and training and capacity building for mapping and portal usage. Part of its continuation will happen through the further development of the GEO-Wetlands initiative.

2. Main achievements and innovations of the SWOS project

2.1 Alliances and cooperation established

2. 1. 1. Establishment of a user network

As a baseline for the development of the SWOS services, the consortium started by defining the requirements for the SWOS technical components, products, toolbox and portal, as well as the preferred method of user engagement. The definition of user requirements was undertaken with users (who are not part of the SWOS team) operating in the field of wetland management through consultation and feedback, questionnaires and workshops. This SWOS user group consists of local, national, regional and global working organisations, in between local wetland managing organisations, Ramsar national authorities, MedWet and other regional frameworks, GEO/GEOBON and the secretariat of the Ramsar convention on wetlands.

Based on the user requirements and ongoing consultation with the user group, so-called ‘service cases’ were selected and developed. These service cases showcase the uses of SWOS services across the local, national, regional and global level. Paragraph 2.2.6 provides some examples of the services cases.

The SWOS team maintained regular contact with users in relation to progress and deliverables of the project. This was done through various means and channels including presentations, workshops and meetings, the SWOS website, newsletter, social media accounts and the SWOS/GEO-Wetlands Community Portal. Following training sessions organized by the project consortium, the SWOS partners have regularly communicated with users to support the production and validation of valuable maps and indicators. This way, the SWOS team has built an effective and sustainable user community for the project duration and beyond, ensuring the long-term sustainability of the SWOS services.

2. 1. 2. GEO-Wetlands

GEO-Wetlands, initiated and led by SWOS, was officially approved for the work programme of the Group on Earth Observations (GEO) by the GEO-XIII Plenary in 2016. GEO-Wetlands provides a framework for cooperation and for ensuring the long-term availability of mapping and monitoring services for wetlands that are currently being developed by different international projects. As such, its launch provides a huge opportunity for the whole wetlands community. It moves the development of a Global Wetlands Observation System (GWOS), a long-term endeavour of the Ramsar Convention and the wetlands community, from a conceptual stage to implementation.

The SWOS project has made valuable contributions to GEO-Wetlands by providing manpower for managing the initiative, developing a pilot infrastructure for the GWOS Portal, preparing a software toolbox for wetlands mapping and monitoring and finally by demonstrating the value of EO products in pilot cases focusing on different policy and user requirements.

2. 1. 3. Alliances and cooperation with partner projects and initiatives

The SWOS team has actively searched for synergy and alignment with relevant platforms and projects. One such example is the cooperation with the H2020 project ECOPOTENTIAL. After a joint meeting in 2016, a couple of interactions between the two projects was established. For example, Water Quality products derived for a SWOS Greek service case site was shared with the ECOPOTENTIAL project for application to their protected area sites, Lake Ohrid and Prespa lakes. Comparisons with field data showed promising results and a validation report was provided to ECOPOTENTIAL. Additionally, common presentations have been prepared for conferences and some SWOS images have been showcased in the ECOPOTENTIAL photo exhibition.

Another example is the cooperation with the Group on Earth Observation (GEO). SWOS has been actively involved in several GEO initiatives and activities. Beside the launch of the GEO-Wetlands initiative, contributions have been made to GEO-ECO, in the GEOSS-Evolve and the GEOSS Community Portal Team (GEOSS stands for Global Earth Observation System of Systems). The SWOS/GEO-Wetlands Community Portal supported the development of the GEOSS Platform widgets and is the first portal that makes use of these widgets. SWOS has gained visibility at GEO events with presentations at several GEO Data Providers Workshops, European GEO Workshops, and side-events of GEO Plenaries.

In addition, cooperation has been established with other projects, including Deymos, Wetland-Radar, Globwetland Africa, Wetland-Afrika, Global Mangrove Watch.

2.2. Scientific and technical publications

Several scientific articles and technical guidelines produced by SWOS partners, have been published and are accessible online at ***https://www.swos-service.eu/publications/.***

2.3. SWOS service lines and service cases developed and implemented

SWOS provides different service lines and service cases to demonstrate the usability and application of satellite-based information for planning, management and reporting.

SWOS SERVICE COMPONENTS:

Maps and Indicators production

Software delivery

Training / Capacity building

Portal (Middleware / Data broker / Clients)

⬇

Service demonstration via multi-level Service cases

2. 3. 1. Maps and indicators production

Service line 1, the Map and indicator production, which has been demonstrated for about 50 wetland sites in Europe, Africa and the Middle East. SWOS has developed standards for the map production, for nomenclatures and has developed nine wetland indicators and many sub-indicators. Standards and tools are available to produce maps and indicators or maps and indicators can be delivered upon request.

Maps and indicators

The SWOS software tools are specifically tailored for wetland mapping, monitoring and reporting and can be applied to derive indicators. These include maps on Land Use Land Cover (changes), Surface Water Dynamics and Surface Moisture, Wetland Inventory and Delineation, Surface Temperature Statistics and Water Quality Statistics.

The project has defined and produced indicators to assess and monitor wetland ecosystem condition and their capacity to provide services. Indicators have been calculated based on Land Use Land Cover and Surface Water Dynamic maps. Change indicators have been calculated where maps were available for multiple years. Indicators for Water Quality status and trends based on user defined aggregation of products, status classes and trend periods have been implemented in the Software.

One developed methodology assesses the capacity of wetland ecosystems to deliver flood regulation services, as well as the existing demand of this service by 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. In terms of its policy relevance, this methodology supports the implementation of the requirements under the EU Directive on the assessment and management of flood risks (2007/60/EC) and the development of 'better environmental options in flood risk management' under the EU Water Framework Directive (2000/60/EC).

For all indicators, sub-indicators for different planning, management and reporting purposes have been introduced and integrated into the software toolbox. Sub-indicators can be used for example directly for reporting under the Ramsar Convention and the Sustainable Development Goals (SDG). The Wetland extent indicator and its sub-indicators - such as Natural Wetland Extent, Artificial Wetland Extent, Vegetated Wetlands Extent, Open Water Bodies and River Water Bodies - have been integrated to calculate the SDG 6.6.1 indicator (the change in the extent of water-related ecosystems over time) for direct incorporation into the reporting sheets. In addition, several products and indicators contribute to SDG 3 (Good Health and Well-being) and SDG 15 (Life on land) reporting.

Validation

A scientific sound validation is an important step for the acceptance of the final satellite derived maps and indicators and for the methodology for their production. Therefore a suite of wetland map products has been validated using both quantitative and qualitative methods. Due to the diversity and timescales of parameters mapped a flexible approach to validation was needed, especially in the acquisition of appropriate reference data. For example, while freely available, contemporary and high resolution satellite imagery (Google and Bing imagery, Copernicus web services and other datasets available through a Web Map Service) was used to validate Land Use Land Cover maps at a representative sample of sites, reference data for water quality and soil surface moisture had to be sourced through collaboration with other researchers at a limited set of point locations.

In this respect, the SWOS approach to validation has been pragmatic and used the best available reference data to provide an indication of the quality of its products. This process has identified a wider challenge in obtaining ground, reference data in and around wetlands. This is partly due to the nature or wetlands (inaccessible and sometimes remote) but also due to some in-situ measures being highly specialised and requiring specialist equipment. For example, this is the case for water quality parameters, which require sampling at specific times, such as before and after an eutrophication event.

Therefore, the SWOS project recommends renewed efforts to continue field visits to measure water parameters in-situ. For the production of a good validation plan, the project recommends the collation of in-situ datasets from the outset to ensure the use of robust reference datasets in estimating map accuracy.

Nomenclature standards and crosswalks

Because of the transitional nature of wetlands, many inconsistencies in mapping and delineation of boundaries appear. Questions like how far the wetland extends and what frequency of flooding is required for an area to be considered as wetland are not defined in the same way by users. As a result the exact upper and lower limits of wetlands are arbitrary boundaries in any definition.

Similarly, when it comes to their classification, different systems are used by different users. In SWOS, the Earth Observation derived mapping products represent essential means for supporting the user's planning and management needs and their reporting obligations; therefore, the nomenclatures and typologies which have been adopted, are those which are recommended in the context of the national, European and global policies for nature conservation and biodiversity.

Harmonization amongst different mapping products, of a single site or various sites distributed along a nation or region, is a prerequisite for any monitoring and assessment program. To this end, crosswalks have been established amongst the different nomenclatures.

Standards and guidelines have been developed along with the mapping production to facilitate future applications. Using standardized nomenclatures allows comparability between different wetland locations and mapping dates and production of harmonized mapping results within countries, regions and globally.

The Land Use/Land Cover (LULC) maps can be produced using three standardized hierarchical nomenclatures: the Corine Land Cover (CLC) nomenclature, the Mapping and Assessment of Ecosystem & Services (MAES) nomenclature and the Land Cover Classification System of FAO (LCCS/FAO) nomenclature. The Ramsar typology has been integrated into all three standard-nomenclatures. The Ramsar typology is the basis for crosswalks between the three nomenclatures. The most appropriate nomenclatures to map Land Use Land Cover outside of Europe will be the CLC-Ramsar and the LCCS/FAO-Ramsar nomenclature.

The three standard nomenclatures are used in combination with the Ramsar typology for covering both the non-wetland and the wetland areas of the total mapping area. For example, CLC incorporates the Ramsar wetland types as two additional hierarchical levels (4th and 5th) of the original CORINE Land Cover hierarchical system. The new classes have been integrated into all the CORINE land categories: “artificial areas”, “agricultural areas” and “forests and semi-natural areas”, as well as “wetlands” and “water bodies”.

Burullus Protected area boundary

Permanently submerged

Temporarily submerged

Never submerged

[1] *Wetlands, 5th Edition, W.J. Mitsch and J.G. Gosselink, 2015*

2. 3. 2. Software delivery / GEOclassifier, the SWOS toolbox for satellite-based wetland information

Service line 2, the Software development, which delivers the freely available toolbox GEOclassifier. The toolbox provides all tools for the production of maps and calculation of indicators. The software is independent and stand alone.
A software team is available to maintain, update and further develop the software.

SWOS has developed various innovative methods and tools for wetland mapping and monitoring. The tools allow for a standardised way to map wetlands using a variety of satellite data sources to generate data from as far back as 1972. Data and maps are inter-comparable in time and space, allowing analysis of temporal and spatial dynamics of wetland changes. Figure 1 compares for example the Surface Water Dynamics of Lake Burullus in Egypt between 1972/1973 and 2015.

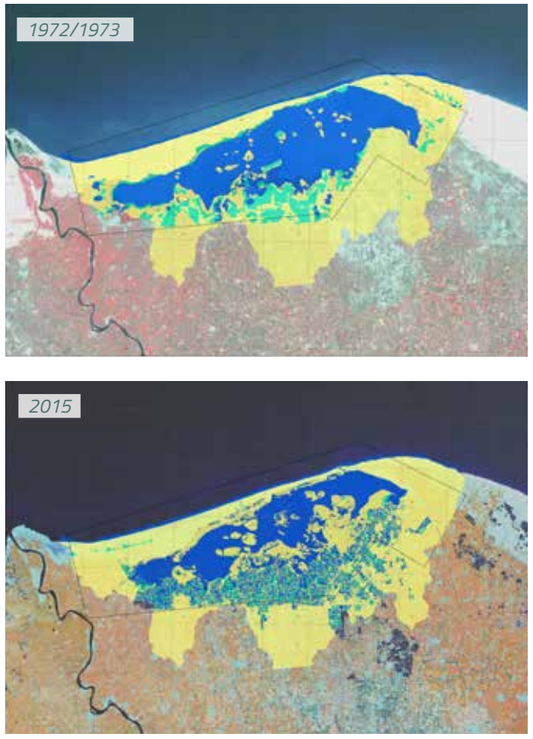


Figure 1: Surface Water Dynamics maps of Burullus, Egypt, based on Landsat data, comparing 1972/1973 and 2015.

The GEOclassifier is the SWOS toolbox for satellite-based wetland mapping. It provides a suite of powerful tools for viewing, processing and analysing remote sensing images. It enables segmentations, classifications and indicator calculations with just a few clicks. It delivers standardized and comparable products and metadata and uses hierarchical nomenclatures (e.g. CLC, MAES, LCCS/FAO) with integrated Ramsar typology. It also allows the calculation of indicators for reporting under the Ramsar Convention and Sustainable Development Goals. In addition, the GEOclassifier allows easy integration of local knowledge.

The GEOclassifier software provides easy access to start wetland mapping. It is applicable to freely available satellite data (optical and radar) of the Sentinel and Landsat missions (available since 1972) as well as data from other sources. The software is available as a free desktop version, ArcGIS integrated toolbox and a cloud-version.

The GEOclassifier cloud demonstrator, located on one of the Copernicus DIAS platforms, can be used for searching and downloading satellite data and performing a Land Use Land Cover Classification using the performance of the DIAS platform. An open source software for the pre-processing and analysis of radar data based on the ESA SNAP toolbox has been developed and provided as Python package “pyroSAR”. This allows an automated processing of radar data (e.g. Sentinel-1, Envisat) into an “analysis ready data” format.

GEOclassifier GUI is the freely available desktop software toolbox. The most important parts of the GEOclassifier GUI have been integrated into the cloud, into the DIAS platform Mundi. The GEOclassifier Cloud demonstrator has been published during the Ramsar convention COP 13 in Dubai in October 2018. With the cloud version, it is no longer necessary to download all the satellite data to the desktop from different acquisition dates to cover the dynamic changes in wetlands. Now data can be transferred to the mapping area within the cloud and only the final map will be downloaded.

This is a major achievement for the wetland community and will encourage users to use the new technique for wetland monitoring and management. Therefore it is intended to transfer the demonstrator into a permanently available cloud version after the life time of the SWOS project and distribute it via subscription fee to cover the cloud and service provision costs.

2. 3. 3. Training and capacity building

Service line 3, training/capacity building. Although satellite data and tools are available for free, in many countries the capacity to utilize satellite data and apply new technologies is not available, there is a lack of trained staff and the integration of new satellite-based tools into the daily work needs permanent and solid support to overcome these obstacles. There is a SWOS training program and training team available to teach users at different working levels how to produce new maps and indicators.

The SWOS team has organised capacity building activities for users at different levels. These activities included training sessions on wetland mapping, user workshops and a technical readiness workshop, which helped create a common understanding of the methodological developments under SWOS.

In 2018, the SWOS team organized a training workshop to teach user organizations how to apply and work with satellite data for wetland mapping, how to use the SWOS service components (maps and indicators, software tools and the portal), and to demonstrate how to integrate SWOS products into selected service cases, to support for example Ramsar or SDG 6.6.1 reporting.

SWOS engaged with users and stakeholders who are responsible for management and protection of specific wetland sites. Below a few examples of wetlands around the world that have received support by the SWOS team.

2. 3. 4. SWOS / GEO-Wetlands Community Portal and Knowledge Base to publish and connect satellite-based wetland information

Service line 4, the SWOS / GEO-Wetlands community portal makes available all maps produced in the framework of SWOS. In addition, the portal connects wetland information with freely available European and global layers that are useful for wetland monitoring. The portal will be maintained after the lifetime of the SWOS project and provides the possibility to integrate additional layers.

The SWOS Community portal makes available geospatial datasets for download and visualization. Users can find for each wetland site additional data, such as images and videos and an overview of available satellite data. Also, different data have been made available at national, continental and global scales. For example, geospatial products, external layers and databases, national views on wetlands dependent on data availabilities. In SWOS, geospatial thematic map products have been produced for many wetlands. All of them are visualized in the portal and can be downloaded. An example map can be seen in Figure 2 for Laguna de Fuente de Piedra in Spain.

Maghreb and West African countries

A 3-day training session was organized to train French speaking users from Maghreb and West African countries in using earth observation data for wetland and water monitoring, based on the products developed by the SWOS project. Satellite data acquisition was introduced. Participants were able to apply what they learnt and to produce their first Land Use Land Cover and Surface Water Dynamics maps; using some of the SWOS nomenclature systems (e.g. CLC/Ramsar) and satellite data related to their sites.

Participants showed a very high interest in the SWOS approach used for the delineation of potential wetland areas (based on combining spectral, topographic and climatic indices), especially to help them in the development of wetland inventories at local (river basin) or national scales. Potential collaboration with local users to gather field data for map validation was also discussed, with a strong willingness of some users to be involved in this process to increase the quality and reliability of final results.

External maps, such as the Global Surface Water and the Copernicus Land Service High Resolution layers, have been integrated into the portal to allow an interactive comparison of maps. Some SWOS indicators have been calculated automatically based on the Land Use Land Cover maps available in the portal. In addition to the visualization and download of maps, statistics have been calculated and made available within the portal without the need for data download.

Users can search within the Global Earth Observation Systems of Systems (GEOSS) directly from the portal using the GEOSS Platform Widgets, which allows data discovery and visualization beyond the geospatial data made available from the SWOS / GEO-Wetlands Community portal.
The story lines in the SWOS Community Portal explain different aspects related to wetlands, satellite data and thematic products, which have been used and produced in the framework of the SWOS project. Text and images are linked with geospatial maps that can be explored interactively.

The Geo-Wetlands Knowledge Base provides an entry point for users to find case studies, courses, software, methodologies and datasets related to remote sensing of wetlands. As Geo-Wetlands is an open community, the portal is not limited to SWOS-related information but includes a wide range of resources from many different projects and will continue to grow through future contributions.

Sebou River basin

The Sebou River basin is one of the largest river basins in Morocco with 6 million inhabitants, 25% of the national groundwater reserve and 30% of the national surface water. Oued Sebou is the main permanent river of the country but also the most polluted one. The river basin agency ABH Sebou is in charge of water resources management through consultation with national and regional public bodies. ABH Sebou decided to work with the SWOS project to assess how satellite data could help monitoring water resources and their uses, and then be integrated in its operational water information system. The exchanges with ABH Sebou and local stakeholders allowed identification of priority areas where SWOS products could provide valuable inputs:

- Support for flood risk management: monitoring flooded areas and comparison with hazard maps defined with models, integration of soil moisture into early warning monitoring network (today based on river water levels/flows), water retention maps based on land coverage;
- Identification of and monitoring pressures on water resources using Land Use Land Cover maps (baseline and change maps);
- Inventory and delineation of wetlands with a priority on the four restoration areas identified by the river basin management plan: Boujaoui, Dayat Hachlaf, Dayet Aoua and Dayat Afenourir;
- And finally, monitoring vegetation cover around water reservoirs to assess silting risk.

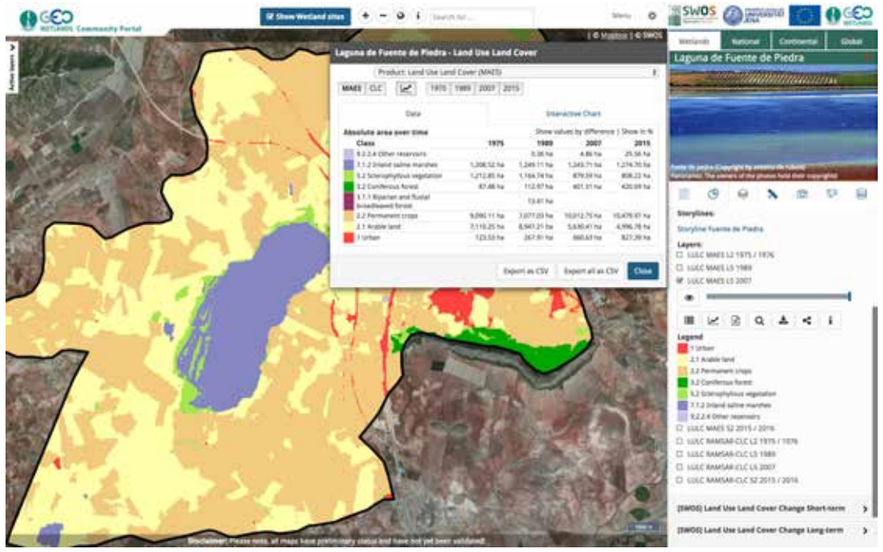


Figure 2: Example visualization of Land Use Land Cover dataset within the SWOS portal for Laguna de Fuente de Piedra in Spain.

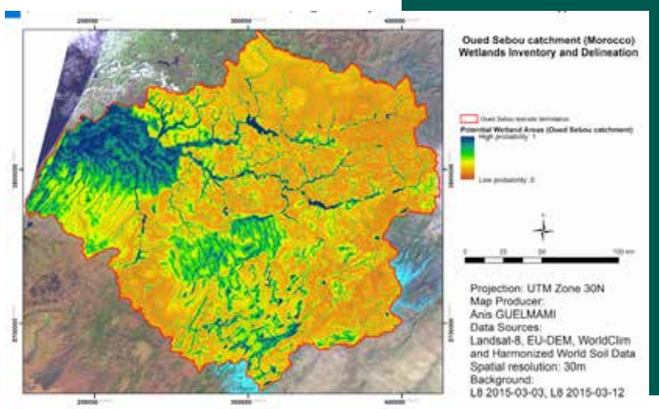


Figure 3: Wetlands Inventory and Delineation map for the Oued Sebou catchment

2. 3. 5. Service cases

'Service cases' have been introduced in the SWOS project to demonstrate to users working on local, national and global level how satellite-derived information can be applied and integrated into very different services for planning, management and reporting. The service cases have been developed based on user requirements from organizations in Europe, Africa and the Middle East. Maps and indicators for about 50 wetland sites have been produced using the GEOclassifier toolbox and provided the basis for the service cases.

The service case approach of SWOS has been applied during the project to translate the technical abilities within SWOS to their practical application within a certain political and geographical context specified by the SWOS users. The development of service cases has linked the SWOS products to policy processes and assisted identification of issues for the SWOS project to engage with. Moreover, the approach provided an opportunity for users to engage in the process of SWOS.

Based on the user requirements and ongoing consultation with the user base, a selection of service cases was developed to showcase the possibilities of the SWOS project across the local, national, regional and global levels. The service cases contained five key elements:

- A policy context (e.g. EU Habitats Directive, Ramsar Convention, MAES)
- Description of the users in this policy context
- Information needs (e.g. Habitats Directive Article 17 reporting)
- User requirements (e.g. baseline year, spatial resolution, nomenclature)
- Matching SWOS products and their specifications

Several areas, ranging from small wetlands, to large catchments and basins were defined as pilot locations for analysis of policy measures taken by the respective implicated authorities. Each service case has been implemented and tested in at least one pilot site during the project timeframe. These sites included the Ewaso Ng'iro North River Basin in Kenya, the upper Niger and Inner Niger Delta basins, the Hawizeh Marshes and Central Iraqi Marshes in Iraq, wetland sites in Spain and Italy, a peatland site in Sweden and the Greek Ramsar sites.

These service cases showcase the contribution of the SWOS project to the monitoring and assessment of wetlands in the context of the most important policy frameworks concerning wetland management and monitoring.

2.4 Impact on wetland management and conservation

In the context of the SWOS project, 'users' have been defined as institutions and individuals with a need for remote sensing to monitor natural resources and wetlands to provide data towards monitoring and management. They work at global, regional to local levels, including those on the ground with a direct role in managing wetlands, implementing policies and reporting to focal points. They use SWOS products to support the policies they implement. This includes site managers, Non-Governmental Organisations (NGOs), research institutions and national, regional and local natural resource agencies. Users are bound to different policy contexts in which they operate for the management and conservation of wetlands. The policy context and the resulting reporting and monitoring obligations are significant drivers of ecosystem monitoring inside and outside of Europe.

For improved conservation and management of wetlands, users wanted to save time and resources in wetland monitoring e.g. through improved data retrieval. Furthermore, more efficient and consistent monitoring of wetlands which is not restricted by political boundaries helps improve management of transboundary wetlands. As a principle, the SWOS wetland site delimitation considers the hydrological and ecological characteristics of a wetland, not only administrative limits of wetlands. This allows for a much more integrated assessment of the wetland and its threats.

SWOS is providing standardized and comparable information about wetlands. Consequently, the SWOS methods and tools allow to get the big picture of the status of the world's wetlands as requested by the Ramsar Convention on Wetlands for Ramsar and SDG reporting.

Examples of how SWOS services have contributed to improved management and conservation

The following two examples illustrate how SWOS services have contributed to improved management and conservation of wetlands.

- **Ramsar Convention on Wetlands: Greek Ramsar sites**

A notable example of how SWOS has contributed to wetland management concerns the ten Greek Ramsar sites and their catchment areas. The areas occupy almost 17% of the inland Greek territory. The SWOS service generated a national application for mapping and assessing the spatial extent of the wetland ecosystems (an indicator under the Sustainable Development Goal 6.6.1) within and outside the Greek Ramsar site boundaries (121,307 ha and 57,595 ha respectively for the year of 2017).

The assessment of changes in wetland extent between 1987 and 2017 revealed both gains and losses. These resulted from human activities, management practices and natural succession processes. The mapping of all ecosystem types at the catchment level enabled the capture of changes in wetland extent along with their causes; i.e. wetland conversion to agriculture (2,241 ha); withdrawal of farming in favour of wetlands (3,404 ha); wetland uptake from dry semi-natural and natural land (3,255 ha) etc.

These mapping and assessment results provide a knowledge base for the national and regional authorities of the Ramsar sites, National Parks, water districts and others to identify areas for conservation and restoration and to direct sustainable management of water, natural, and agricultural resources from a hydro-ecological perspective.

- **Assessment of land transformation to shape national wetland policies - the Kilombero Floodplain, Tanzania**

The SWOS team has not only cooperated with local stakeholders, but also with specialists from international organizations in assisting local and national governments. Such is the example of SWOS activities in the Kilombero Floodplain, Tanzania.

An exponential increase in population during the last two decades has caused uncontrolled agricultural expansion and deforestation in the area. This has affected the ecosystem services the wetland provides as well as its local fauna and flora, and has triggered several social conflicts. The University of Bonn (a SWOS project partner) and the Belgian development agency ENABEL have been assisting local and national stakeholders in overcoming the challenges that this Ramsar site faces. By providing mapping products, the SWOS project has allowed for an informed and productive discussion between the many stakeholders. This is a prerequisite to develop and implement good management practices that allow for sustainable use of a wetland.

The area is going through a development phase to modernize farming practices to improve food security and sustainability. By studying trends in land use and several indicators, wetland managers can now develop strategies that will support economic development using knowledge of natural resources available in the floodplain and the impacts they face from human activities.

Figure 4: Local communities at Kilombero basin are supported by the ecosystem services that the wetland provides
© Frank Thonfeld, University of Bonn

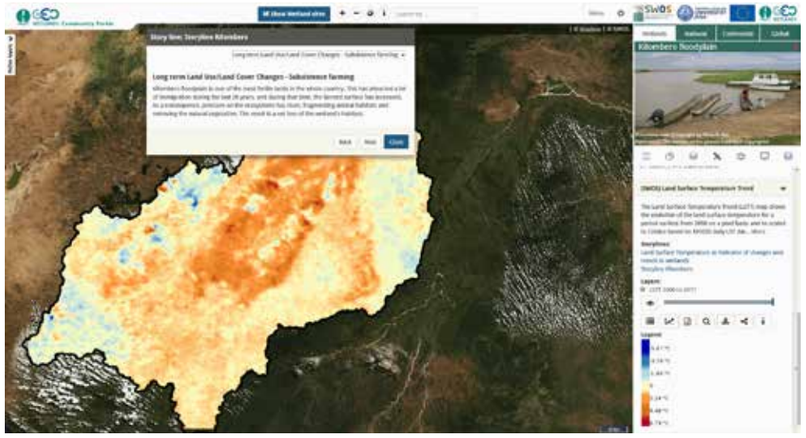


Figure 5: Land Use Land Cover and Land Surface Temperature map of the Kilombero floodplain

2.5 Contributions to EU and global policy development, implementation and reporting obligations

Multilateral Environmental Agreements (MEAs) and other global processes mention wetland habitat conservation and ecosystem service safeguarding numerous times underlining their importance for the international conservation community. The SWOS project makes major contributions to the improvement of global mapping, monitoring and assessment of these important ecosystems and their services, through its standardized monitoring service for wetland ecosystems based on Earth Observation satellites and by providing a unique entry point for users to easily locate, access and connect wetland information through the community portal.

SWOS partners have engaged with users, policy makers and other stakeholders of the Ramsar Convention, UNFCCC and the Convention of Biological Diversity to stimulate discussions around the use of satellite remote sensing for wetland inventory, monitoring and assessment.

The SWOS services contribute to the 2030 Agenda for Sustainable Development by supporting countries in meeting their reporting obligations for the Sustainable Development Goals (SDG). For example, SWOS products and tools are designed to compute ecosystem extent data required to monitor SDG Indicator 6.6.1: "change in extent of water-related ecosystems over time" as well as to meet the priorities set under the UN Convention to Combat Desertification "Land Degradation Neutrality" (LDN) principle (also targeted under SDG 15).

SWOS Land Use Land Cover products have been used to compare Ramsar site boundary information from the World Database of Protected Areas (WDPA) or Ramsar database with the spatial distribution of important wetland habitats at 29 sites in 15 countries. This approach demonstrates how protected area designations can be designed or revised to offer the best possible protection for natural features of importance.

In Europe, SWOS helps ensure that the European Union takes a leading role in wetland management by contributing to policy making and sustainable decision making. SWOS has supported in raising the discussion for a refinement of EU Strategies and Directives to better integrate wetland ecosystems and the development towards a European environmental model for wetland management and maintenance of wetland ecosystem services.

Moreover, SWOS has introduced validated tools and methods to guide EU action towards achieving no-net-loss and restoration targets and objectives for wetland ecosystems. SWOS products have fed the analytical framework for Mapping and Assessment of Ecosystem Condition in the EU (MAES). This framework provides a knowledge base on ecosystems and their services which can help deliver on the EU's Biodiversity Strategy to 2020.

3. SWOS Policy Recommendations

I. Considering the natural boundaries of wetlands allows for a holistic approach to its management, ensuring that the right conservation and restoration connectivity measures are taken in response to the urgent need for halting ecosystem loss, and sustaining the delivery of precious ecosystem services.

The established conservation efforts and restoration measures undertaken globally and in Europe are partialized and do not consider wetland ecosystem structure and function in a holistic manner (1)

Environmental policies lack specific quantifiable indicators to monitor the conservation and management of wetland ecosystems (2)

SWOS provides a clear solution to (1) and (2) that ensures the use of a holistic approach in wetland management and conservation and a quantifiable indicator to a policy target: The "hydro-ecological" delimitation of wetland ecosystems

II. Mapping the activities from multiple sectors and sensitive areas is key, while considering multiple approaches (classifications, nomenclatures,...) in characterising and assessing wetlands will mislead spatial localisation and prioritisation of management interventions.

Mapping the activities from multiple sectors and sensitive areas is key, while considering multiple approaches (classifications, nomenclatures,...) in characterising and assessing wetlands will mislead spatial localisation and prioritisation of management interventions, and therefore, ... Urgent agreements among scientists, practitioners, and policy makers need to be reached on widely used ecosystem-based definitions using coherent delimitations, delineations, and nomenclatures to allow for proper assessment and monitoring of wetlands

III. Whilst most environmental actions that are derived from legislation are relevant to wetlands, dedicated EU policies targeting wetlands explicitly are very necessary (and missing) enabling the implementation of EBM actions and ensuring the delivery of practical results on the ground in benefit of wetland ecosystems

Whilst most environmental actions that are derived from legislation are relevant to wetlands, dedicated EU policies targeting wetlands explicitly are very necessary enabling the implementation of EBM actions and ensuring the delivery of practical results on the ground in benefit of wetland ecosystems

4. Vision for the future of Satellite-based Wetlands Observation

In the coming years, after the current project lifetime, SWOS aims to continue providing a service for satellite-based wetland monitoring to users. This service could exist as ready-made maps and indicators to users that do not have the capacity to perform their own satellite image processing. In addition, SWOS will offer the developed software in combination with training and capacity building for mapping and portal usage. Part of the continuation of SWOS will happen through the further development of the GEO-Wetlands initiative.

» Vision 1
EO will help to stop the process of declining wetlands

The vision of SWOS is that methods and tools developed within SWOS will help to make a change and reverse the process of declining wetlands. In addition, the vision is that SWOS supports the mission of the Ramsar Convention: "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." The vision of the Ramsar Convention, formulated in the fourth Ramsar Strategic Plan 2016–2024 is also the vision of SWOS: "Wetlands are conserved, wisely used, restored and their benefits are recognized and valued by all."

» Vision 2
Implementation of SWOS products

SWOS products proved to enable the development of widely applicable means for properly characterising, assessing and monitoring wetlands. The vision concerning SWOS products includes their use to assess the condition of wetlands and pressures exerted upon them, contributing to improved international and national monitoring and reporting.

This will be insured through 1) the adapted SWOS nomenclature based on habitat classification ensuring the identification of transitional ecosystem types that hydro-ecologically belong to wetlands; and 2) solutions using EO to effectively map these habitats supporting wetland inventories processes at different levels and more importantly facilitating international cooperation on transboundary wetlands including, among others, the RAMSAR site designation.

» Vision 3
Implementation of SWOS tools

SWOS software tools are easy to use and wetland mapping tailored. The vision concerning the SWOS tools is that the integration of the GEOclassifier in the cloud and the direct and easy access to freely available satellite data will help to overcome still remaining barriers for the integration of satellite-based techniques into the daily work of wetland practitioners.

» Vision 4
New products and functionalities for the software toolbox

The SWOS software toolbox covers all steps for the production of satellite-based maps and indicators. However, additional functionalities and automated workflows could improve and extend the usability, better exploit available satellite data and maybe deliver answers to new questions about the status and trends in wetlands.

» Vision 5
Web- and cloud-based processing of satellite data

Processing and analysis of satellite data is nowadays transferred to cloud provider to conduct processing close to the data. Through the development and provision of web-based processing tools users do not need to download data and install software locally on their computers. Within SWOS, some tools have already been transferred to the cloud (e.g. GEOclassifier cloud) and further prototypical tools have been developed (e.g. an instance of the CEOS Open Data Cube for individual wetlands containing Landsat data and a "Surface Water Dynamics Toolkit" based on Sentinel-1 time-series data). All these tools allow users a simple processing and analysis of satellite data within a web browser, which will be increasingly important for a satellite-based wetland observation system in the future.

» Vision 6
SWOS Portal will become a unique entry point for new wetland information

The vision concerning the portal is, that it will remain a unique entry point for wetland information in the future, that new maps will be integrated and new wetland information sources will be connected via the portal. The GEO-Wetlands Community Portal developed within the SWOS project is seen as the sharing platform of wetland-related geospatial data in the future.

Geospatial data is made available based on thematic and technological standards. Data management plays a key role in all projects and thus the portal can support projects in enabling open data and open science policies. The vision is that the portal will provide not only access to geospatial data from SWOS but also from other wetland-related projects. It is envisaged to allow software toolboxes, such as the SWOS toolbox, to produce maps that can be directly uploaded to the portal and made available either for a limited user group or for the public.

» Vision 7
Defining service cases for future exploitation

The existing SWOS service cases could provide a basis to increase replication opportunities within other basins and countries in Europe and beyond within different (policy) contexts:

- European water directives and water management at basin level
- International frameworks and conventions
- Wetlands at local/national level
- Scientific frameworks (e.g. Climate change, GEOSS)
- SWOS and MAES

Continued engagement with authorities and managers at different levels – the users – will increase their awareness of SWOS and will show the potential of the SWOS service for wetland monitoring and management. Moreover, collaboration between SWOS project partners and users can uncover additional practical issues and opportunities to be addressed through further improvement of the products and tools developed under SWOS.

» Vision 8
GEO-Wetlands

The GEO-Wetlands Initiative is expected to provide a long-term home and management body to keep the achievements and products of SWOS and several other projects available for the user community. This will be in an operational, policy and user driven system that is being co-designed and developed by the community in a collaborative effort. This initiative will strengthen global cooperation, target funding and establish the necessary structures for the sustainability of the developed toolboxes, products and services.

» Vision 9
Geographical dissemination

SWOS has been demonstrated through service cases from local to global lever. Nevertheless local, national and regional service cases and the user cooperation were limited to Europe, Africa and the Middle East. One vision is therefore to transfer the technology and tools developed in SWOS to Asia, America or Australia and to extend the user cooperation to new regions in the world and new service cases.

» Vision 10
Service maintenance and improvement

Looking at SWOS as a project with a limited life time and budget, the vision is that in the future new projects, donors and/or a subscription fee for the SWOS cloud services, fees for training and mapping orders will help keep the SWOS service alive, operational and updated and improved.

Dubai and Ramsar Wetland Ras Al Khor, Sentinel 2, 2018-11-30
© contains modified Sentinel 2 Data 2018

Partner

Contributors

» **Eef Silver**
Wetlands International

» **Lammert Hilarides**
Wetlands International

» **Eleni Fytoka**
The Greek Biotope
Wetland Centre EKBY

» **Christoph Schröder**
University of Malaga – European
Topic Centre on Spatial
Information and Analyss

» **Brian O'Connor**
UNEP-WCMC

» **Rene Höfer**
Jena-Optronik GmbH

» **Kathrin Weise,**
Jena-Optronik GmbH

» **Emma Scott**
UNEP-WCMC

» **Eric van Valkengoed**
TerraSphere Imaging & GIS b.v.

» **Javier Muro**
University of Bonn

» **Jonas Eberle**
Friedrich-Schiller-Universität Jena

» **Susanne Thulin**
Brockmann Geomatics Sweden AB

» **Jonas Franke**
Remote Sensing Solutions GmbH

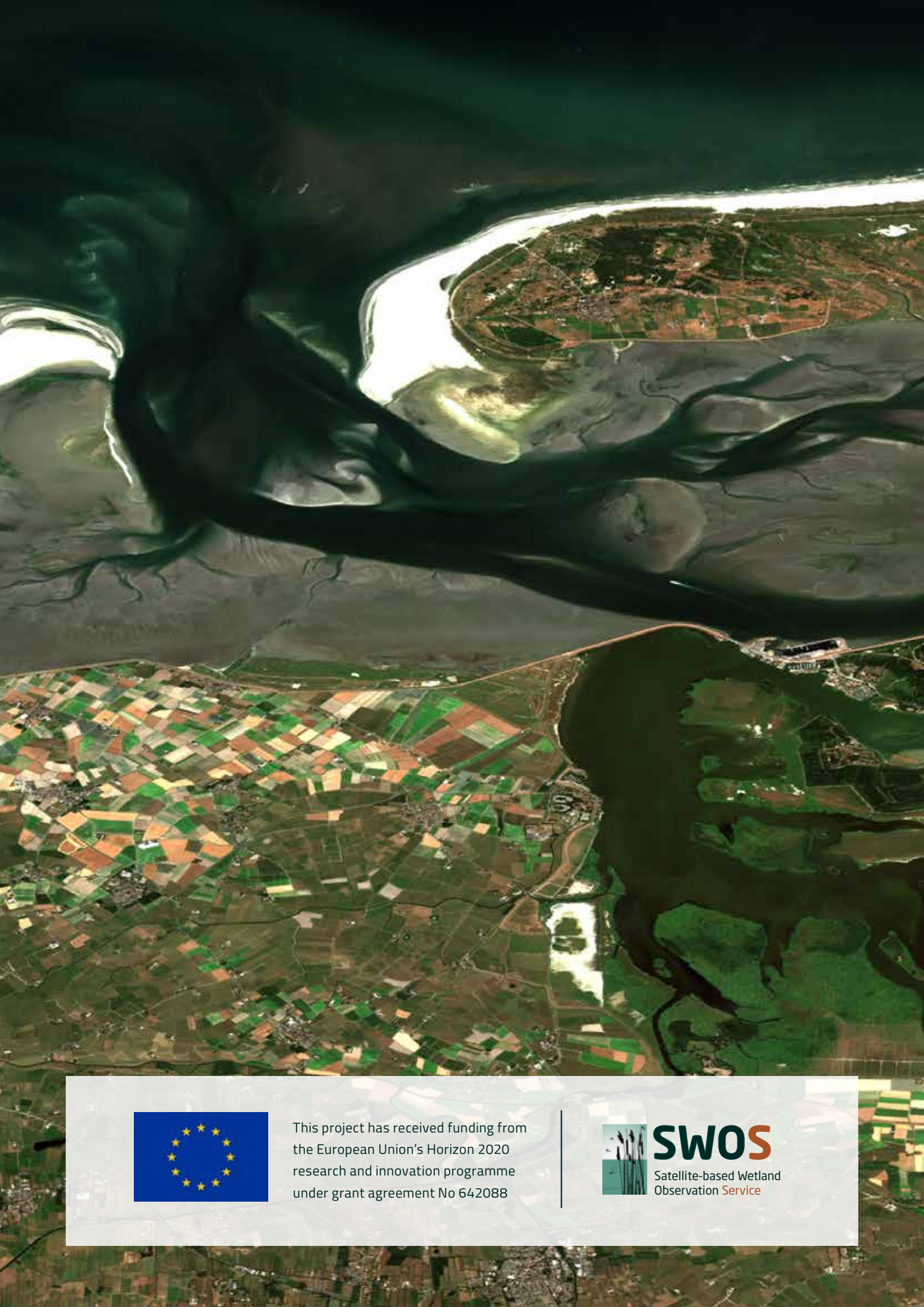
Acknowledgement

The SWOS team would like to thank the SWOS user group and the SWOS advisory board for their support, commitment and cooperation. Special thanks go to the secretariat of the Ramsar Convention on Wetlands for the support, encouragement, assistance and promotion during the life time of SWOS and previous projects, for altogether nine years of cooperation.

Contact

Otto-Eppenstein-Straße 3, 07745 Jena, Germany
Phone: +49 (3641) 200160
E-mail: kathrin.weise@jena-optronik.de
www.jena-optronik.de | **www.swos-service.eu**

Copyright and legal notice



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642088

SWOS
Satellite-based Wetland Observation Service