# *MAES Service Case:*
# *Wetland ecosystem condition mapping*

**Specific request for SWOS to support the MAES WG in preparing documentation for the "Ecosystem Condition" workshop in June 2017**

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# 1. Introduction

From the very beginning of the development of SWOS, the MAES working group expressed high interest in the knowledge improvement regarding wetland ecosystems expected from the project. Since the setup of the MAES WG, it has developed mapping guidelines (Erhard et al. 2016) and a European ecosystem map[1] as baseline information for further monitoring and update of European ecosystems at habitat level and for underpinning biodiversity scales. Even though the work accomplished so far is a fundamental step forward towards a harmonized ecosystem map, wetland ecosystems have been underrepresented in the European ecosystem map of 2006 since the ecosystem nomenclature used (EUNIS) does not include in specific cases a detailed classification of wetland ecosystem habitats.

The MAES working group is preparing the workshop on "ecosystem condition mapping" to streamline the efforts done so far with regards to the mapping and assessment of the condition of Europe's ecosystems. The MAES WG has requested directly to SWOS partners a specific document to support the mapping and assessing wetland ecosystem condition for this workshop. This document shall highlight the different elements to take into account for the mapping and assessment of wetland ecosystems with the aim of supporting Member States and the European Commission in their efforts to better describe the situation of wetland ecosystems in Europe.

This document represents the major output of the MAES Service case that shall show how SWOS outputs are useful to support the MAES WG with regards to wetland ecosystem mapping and assessment.

# 2. Definitions of wetland ecosystem condition

"Achieving a good wetland ecosystem condition" is addressed in different policy frameworks and initiatives at global and European levels where the specific elements defined for this purpose depend on the policy context. Below, we recall the criteria of achieving a good wetland ecosystem condition as defined by the most relevant ones.

## 2.1. Ramsar criteria for describing wetland ecological character

Ramsar, as the Convention on Wetlands of International Importance, is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. As a political framework, it aims at ensuring the effective management of wetlands in the member countries. To do so, it has created monitoring requirements to assess regularly (every 6 years) the following indicators for each Ramsar site that should describe the state of the condition and pressures of the wetland:

- Wetland extent

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[1] http://biodiversity.europa.eu/maes/mapping-ecosystems/map-of-european-ecosystem-types

- Wetland area change

- Land cover/use

- Water extent / water regime

- Wetland ecological character (baseline and change/trend)

- Wetland ecosystem services (baseline and change/trend)

Wetland ecological character is defined as "[…] the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time." Contracting parties, i.e. Member States are required to prepare the following Ramsar ecological character description sheet that includes Ecological components, processes and ecosystem services that are relevant to describe the condition of wetlands *(Ramsar Convention, 2008)*:

## 2.2. EU WFD criteria for describing wetlands' good ecological status

The most important objective of the EU Water Framework Directive (WFD) is to achieve a "good ecological status" (GEP) of all waters. The good ecological status represents an indicator for good condition for aquatic and water related ecosystems, i.e. wetlands, and is based upon the status of the biological (phytoplankton, macroalgae, macrophytes, benthos and fishes), hydromorphological (depth fluctuations) and physico-chemical quality elements (transparency, thermal, oxygenation, salinity condition, acidification and nutrient levels) (Borja & Elliot 2007). The ecological status is a perceived or measured deviation from a reference condition. A water body shows a GEP when there are slight changes in the values of the relevant abovementioned biological quality elements as compared to the values found at maximum ecological potential (MEP). These indicators set for the assessment of the GEP within the WFD provide a highlight of appropriate indicators to develop in SWOS (Munné & Prat 2006).

## 2.3. Wetlands' conservation status based on the EU Habitat Directive

Based on the Habitat Directive's Article 17 assessments, good ecosystem condition is reached when a habitat is assessed with a Favourable conservation status knowing this assessment is done for each occurrence of this habitat present in one MS and in one biogeographic region. This assessment is based on four parameters: stable Range and Area, Structures and Functions in good condition and favourable future prospects fact to pressures and threats. The problem with this definition is that these assessments are made for a selection of Habitats of European interest; they can be aggregated by main ecosystems but some ecosystems cannot be fully covered in terms of surface area and habitat type.

Making use of the EUNIS classification of ecosystems, only terrestrial wetlands, i.e. mires, bogs and fens, with the water table at or above ground level for at least half of the year, dominated by herbaceous or ericoid vegetation are considered while water

bodies and coastal wetlands are not covered. Though this constraint exists, SWOS uses this classification due to its political relevance at European scale.

## 2.4. Definition based on EU Red list of habitats

The EU Red List of Habitats provides a straightforward definition stating that habitats are in good condition if they are not classified as threatened (Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU)) in the EU Red List of habitats published in 2016. This approach is defined with a biodiversity and nature conservation perspective based on quantitative (trends of range, area, geographic distribution) and qualitative (abiotic and biotic) criteria. "Of the criteria used to derive the assessment, three were most frequently decisive: Trend in extent over the past 50 years (criterion A1), Trend in quality over the past 50 years (criterion C/D1) and Long-term historical decline in extent (criterion A3). Restricted geographical occurrence criterion B) was decisive in only relatively few cases and Quantitative analysis to assess probability of collapse (criterion E) was used only once" (Janssen et al., 2016).

Regarding wetlands, three types of ecosystems are considered in the EU Red List of habitats: 26 Freshwater habitats, 13 Mires and bogs habitats and 29 Coastal habitats (including terrestrial and marine parts).

# 3. Indicators available from SWOS to assess wetland ecosystem condition

Based on the definitions emphasised in section 2, table 1 summarises the list of indicators developed by SWOS for the assessment of wetland ecosystem condition that will provide support to the stakeholders and the Member States involved in the MAES process, and more specifically for the ones working on the assessment of their ecosystem condition.

| Elements | Indicators available from SWOS to assess wetland ecosystem condition |
|---|---|
| **Biological Elements** | |
| **Ecological components** | - Wetland delimitation and delineation (ha covered)<br>- Change in surface water dynamics, submergion frequency (%)<br>- Land use/Land cover/ecosystem maps (ha of habitat / LC type)<br>- Water Quality:<br>    o Concentration of chlorophyll a (concentration, µg l-1)<br>    o Coverage of helophytic vegetation on the coast based on ecosystem/land cover map (ha) |
| **Ecological processes** | - Change in land use/ land cover change maps indicating surrounding pressures (%) |
| **Ecosystem services** | - Flood & erosion regulation potential |

| | |
|---|---|
| | - Wetland ecosystem potential to supply "Maintenance of nursery populations and habitats" <br><br> - Carbon storage (under development) |
| **Hydromorphological elements** | |
| Depth fluctuations | Surface water dynamics: Relative measurement of the change in level (cm) |
| **Physico-chemical elements** | |
| Transparency | Secchi Depth (depth, m) |
| Trophic state of the water body | Coloured Dissolved Organic Matter (CDOM) (absorption, $m^{-1}$) |
| Physical disturbance | Total suspended matter (TSM) (concentration, mg $l^{-1}$) |

*Table 1: Indicators available from SWOS products*

# 4. SWOS elements as prerequisites in wetland condition mapping

## 4.1. Delimitation of wetland ecosystems in Europe

To answer a challenge for practitioners to effectively map and assess the condition of wetland ecosystems worldwide, SWOS has developed a reliable hydro-ecological delimitation of wetlands as a tool for a holistic monitoring of wetland ecosystems. This case is also relevant in Europe especially in the case of wetland ecosystems that do not integrally fall under the scope of the EU Water Framework Directive.

Regardless the scale of work, the adoption of this ecosystem-based delimitation supports key environmental policies in Europe and elsewhere ensuring the use of ecosystem basic functional units for the assessments of ecosystem condition and trends, on the major pressures affecting this ecosystem function and the impacts they exert on the services they provide.

As a result a dedicated document was published that provides guidelines for wetland ecosystem delimitation (Abdul Malak et al., 2016) that basically sets the criteria for wetland ecosystem delimitation of the sites considered in SWOS based on which all the SWOS indicators and products are calculated.

## 4.2. Nomenclature for wetland ecosystems

Within its MAES service case, the SWOS project aimed at enhancing, expanding and harmonising the MAES nomenclature to fully cover the wide range of wetland ecosystems. To this target, new classes are introduced to the wetland ecosystem nomenclature such as rice fields, wet grasslands, wet heathlands, and riparian forests. These newly included classes, although belonging to agroecosystems, grasslands, heathlands and shrubs, woodland and forests (under the MAES

nomenclature) are mapped and assessed as being part of wetland ecosystems in SWOS. As such, in 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). Also, modifications are done in class name definitions to become more representative and discrete as well as to follow relevant wetland research considerations.

As a result, the technical document "The wetland ecosystems in MAES nomenclature" was published (Fitoka et al. 2017)[2]. This document provides a comprehensive list of the wetland ecosystem classes that SWOS is proposing to be integrated in the MAES nomenclature along with application guidelines and mapping conventions. Cross walks between the MAES wetland classes with the Ramsar types, EUNIS and CLC classes are provided to ensure a user-friendly shift amongst each other as well as for documentation needs. These efforts developed within SWOS support and complement the MAES process in the considering wetland ecosystems in the implementation of key policy areas, namely within the efforts to achieve Target 2 Action 5 of the EU Biodiversity Strategy to 2020.

### 4.2.1. Feasibility of nomenclature mapping

The ongoing work within SWOS now are focusing on testing the feasibility of detecting and of mapping the habitats as defined by the improved MAES nomenclature proposed by SWOS that will be included in the upcoming SWOS wetland habitats delineation guidelines (end of 2017). The guidelines under development will set the mapping rules for wetland habitat delineation, whenever feasible, and the considerations of these habitats within wetland ecosystem assessments.

It should be nevertheless 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 data or even when using ancillary data. 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 the majority of 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. 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, Sentinel-3 provides data on sea and land surface temperature and water colour. The Landsat and ENVISAT legacies ensure historical assessments of ecosystem changes. By making use of these latest Earth Observation (EO) and IT technologies, new standards can be set-up after assessing the feasibility of EO to support the EU MAES initiative, international conventions (e.g.

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[2]     http://swos-service.eu/wp-content/uploads/2017/05/SWOS_MAES-wetland-component-v1.2.pdf

RAMSAR) as well as multi-level policies and thus identifies benefits and limitations of EO.

# 5. SWOS products in support of mapping and assessment of wetland condition and their services

This chapter summarises the elements of the products developed by SWOS that are available to support the wetland ecosystem condition mapping and assessment. It informs about the progress made for each product and how it fits the purpose of ecosystem condition mapping not only at site level, but also at European scale. Each product is introduced by a summarising table about the source imagery, the derived indicator, the purpose of the indicator as well as the frequency and spatial resolution.

## 5.1. Surface Water Dynamics

| Indicator | Seasonal water regime |
|---|---|
| Purpose | Climate change and human disturbance can be assessed based on temporal water regime changes |
| Satellite images | Sentinel-1A/B, ENVISAT-ASAR |
| Frequency | 6 days for Sentiel-1 |
| Scale/Resolution | 20 meters |

The mapping of seasonal open water dynamics of a wetland area quantifies seasonal and permanent water surface areas (ha). Maps of multiple years serve as input for long-term change analysis in surface water dynamics indicating the pressures on wetlands such as drought increase, pumping of underground water or artificialisation of wetland ecosystems.

The SAR-based surface water dynamics (SWD) product utilises the high revisit rate by Sentinel-1A/B (over 100 images per year) to develop a surface water dynamics indicator with a very high temporal density. In a first step, single binary water body maps (standard mask, SM), showing the area covered by surface water, are produced from the imagery and then aggregated to water dynamics maps by counting the number of water detections per pixel, normalised by the number of valid data points. Figure 1 provides an example of a surface water dynamics map for the Camargue area (France), indicating the frequency of submersion of each pixel in time.
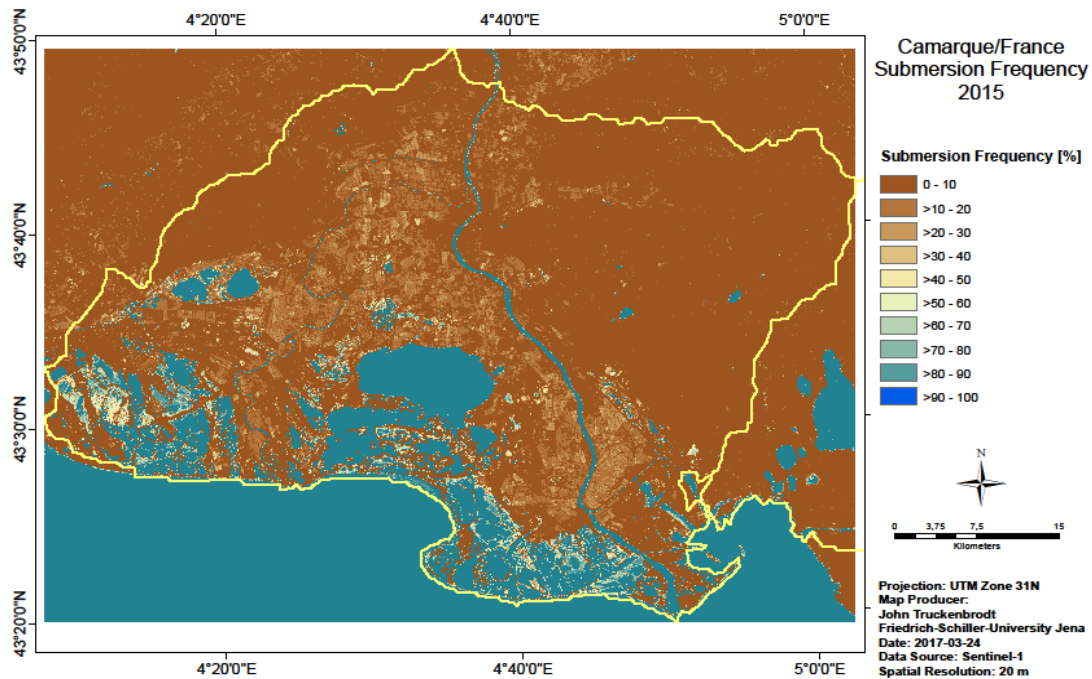
*Figure 1: Camargue (France): submersion frequency 2015 derived from Sentinel-1 Synthetic Aperture Radar (SAR) data. Acquisitions were available for 75 days.*

The optical SWD represents a simple approach to derive the minimum and maximum water extents and non-flooded areas over a single season and is produced using a time-series of optical (Sentinel-2A or Landsat-8) images. The difference between the maximum and minimum water extent represents the total seasonal flooding in a wetland. An example of optical SWD maps is given in Figure 2.

Since water is the essential element of wetland ecosystem, the presence and dynamics of surface water are crucial to assess wetlands' ecosystem condition. This product is to be used as an indicator for the assessment of water regime and the impact of human disturbance (agriculture, urbanisation, etc.) and climate change within wetland ecosystems. Thanks to the new Sentinel imagery and SAR-based techniques, a very rich image collection can be achieved at any weather condition for any part of Europe, with a revisit time of six days.
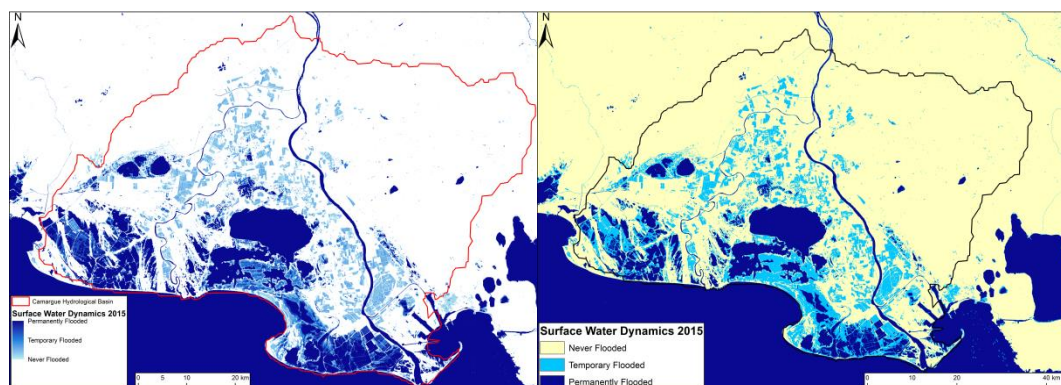


*Figure 2: Camargue (France): Surface Water Dynamic maps of the Camargue using L8 optical data (left: temporal frequency; right: temporal dynamics).*

## 5.2. Land Use Land Cover and its changes

| Indicator | Land cover state and dynamics |
| --- | --- |
| Purpose | Account for land cover and ecosystem distribution as well as monitor pressures (agriculture and urban expansion) on wetland ecosystems over time. |
| Satellite images | Sentinel-2, Landsat series |
| Frequency | Yearly (weekly changes possible with S2 images) |
| Scale/Resolution | 10 meters (S2), 30m (Landsat |

The quantification of Land Use Land Cover (LULC) and LULC changes (LULCC) in a time period are crucial indicators for monitoring wetland ecosystems and their surroundings. They allow discovering changes in LULC over short (Seasonal) or long periods (e.g Decades) of time and are useful for identifying change trends like e.g. accelerated conversion from natural areas to agricultural areas. Short Land Cover change detection on a weekly to monthly basis of especially dynamic land cover types e.g. harvest of fields or reeds, changing inundation levels, deforestation, or sudden land movements, among others, allows accounting for the high (within a year) dynamics of many wetland related land cover types in monitoring and assessing the wetland ecosystem status, services and trends. The quantification of LULC and LULCC is performed by intersecting LULC maps of various periods over time (e.g. changes happening between 2005 and 2015).

The LULC map is derived using an object-based approach depicting the seasonal LULC of segments presented in vector format. Time-series of optical data covering a complete growing season or year are used as a basis for segmentation into logical (homogeneous) units, which are then classified based on spectral and temporal characteristics. When a time-series is not available due to cloud coverage, a single image is used to derive LULC, usually yielding a lower accuracy for certain classes. Based on the nomenclature guidelines and various crosswalks between classification systems, land cover maps can easily be translated in ecosystem maps. Figure 3 provides an example of a LULC map of Fuente de Piedra wetland (Spain) using the adapted MAES nomenclature.

Long-term land use land cover change analysis is done through a Post Classification Comparison of two separate years. This analysis is useful for identifying change trends such as accelerated conversion from natural to agricultural areas, providing information about recent pressures on wetland ecosystems. Figure 4 provides an example of LULC change indicator showing the variations between 1989-2017 for the wetland ecosystem at Fuente de Piedra (Spain), showing the expansion of transport infrastructure and change to more intensive (i.e. water demanding) agriculture.

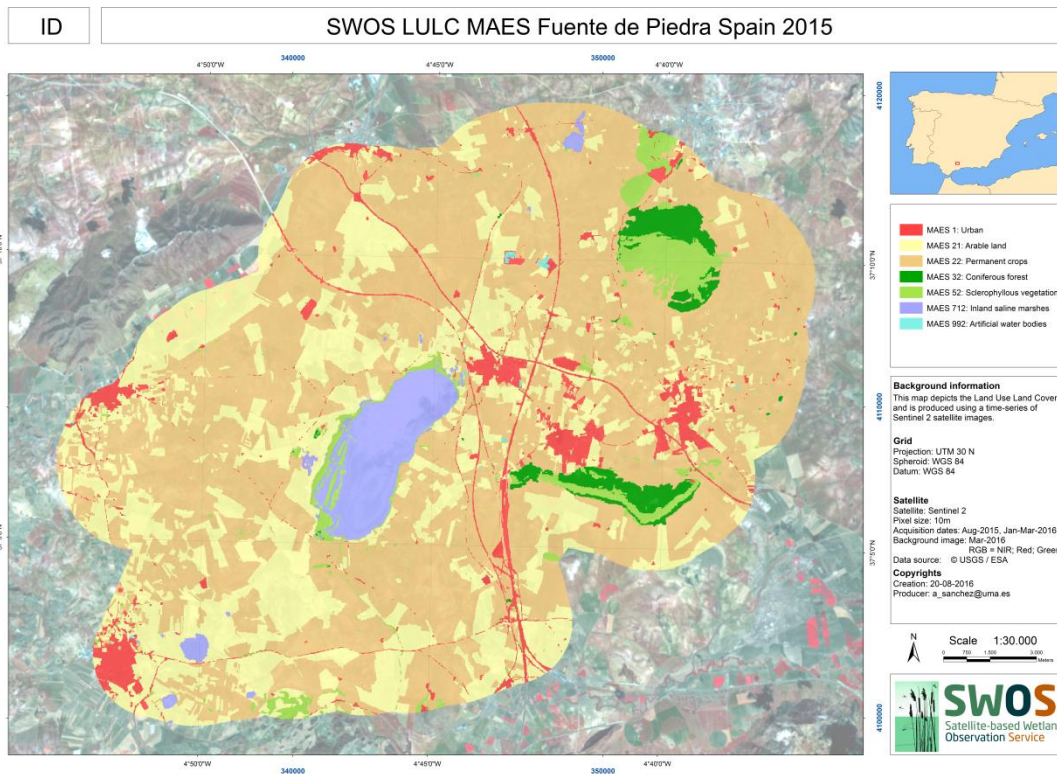*Figure 3: Fuente de Piedra (Spain): Land Use Land Cover map of Fuente de Piedra wetland using the adapted MAES nomenclature*
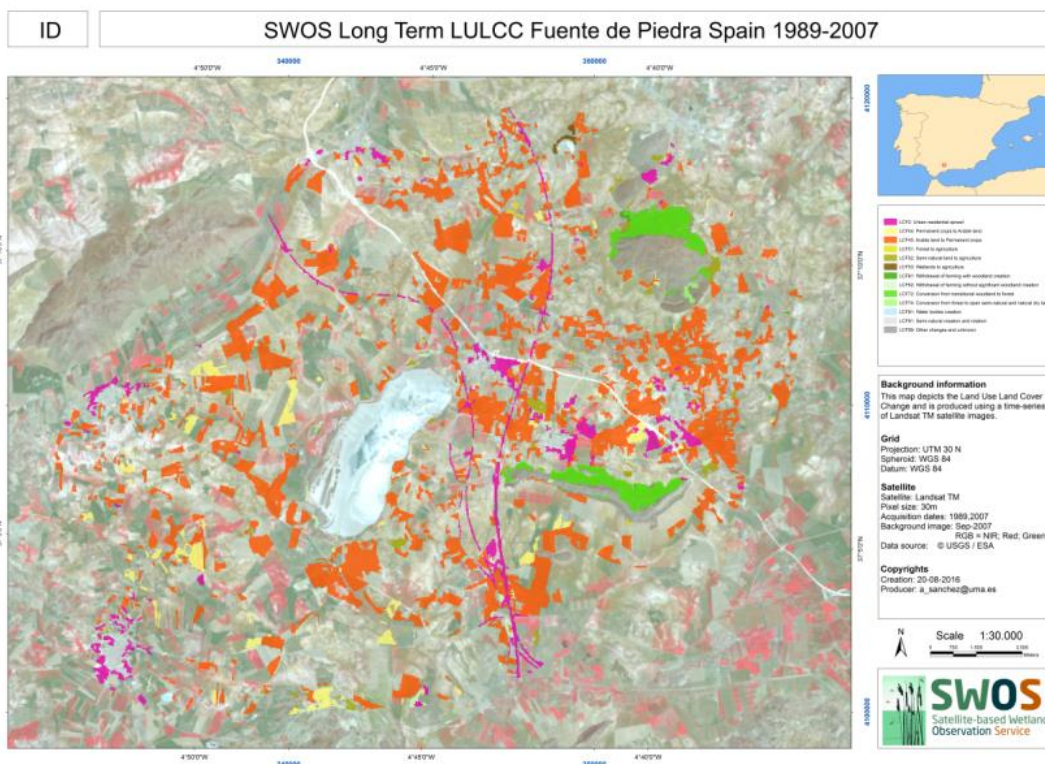


*Figure 4: Fuente de Piedra (Spain): Long term Land Use Land Cover change map of Fuente de Piedra wetland, 1989-2007.*

## 5.3. Water quality

| Indicator | Water quality (see sub-indicators in Table 2) |
|---|---|
| Purpose | Ecological status estimations. Indicators for eutrophication and other parameters of water quality. Input to wetland ecosystem service indicator calculation. |
| Satellite images | MERIS (2002-2011), Landsat-8 (2012-), Sentinel-2 (2015-) and Sentinel-3 (2016-) |
| Frequency | daily, monthly, seasonal, yearly or perennial averages depending on user needs/wetland issues |
| Scale/Resolution | 10 meters (S2) to 300m (MERIS) |

Increasingly, restoration of inland water and marine ecosystems, including wetlands, is needed to re-establish ecosystem function and its capacity to provide valuable services. Water quality in freshwater ecosystems including lakes and reservoirs, is an important biodiversity indicator that can serve as a proxy for assessing ecologic and aquatic biodiversity condition.

Remote sensing techniques to assess water quality have initially been developed for open sea and extended to coastal zones, and therefore are in the process of undergoing further refinement to monitor surface water quality in large perennial inland waters, such as natural lakes and water reservoirs. Lakes are optically complex waters where the main active substances can vary independently and development of lake specific water quality algorithms are usually needed before it can be used for operational monitoring. The SWOS water quality (WQ) products that are being produced and validated correspond to the following SWOS sub-indicators listed in Table 2 that shows what aspect these sub-indicators are meant to indicate in the context of ecosystem condition.

| SWOS Sub-indicator name | Used as indicator for: |
|---|---|
| Sub-Indic. 7.1: Chlorophyll a (concentration, µg l$^{-1}$) | Eutrophication |
| Sub-Indic. 7.2: Total Suspended Matter (concentration, mg l$^{-1}$) | Physical disturbance |
| Sub-Indic. 7.3: Coloured Dissolved Organic Matter(absorption, m$^{-1}$) | Nutrient load and contamination, estimation of trophic state of a water body |
| Sub-Indic. 7.4: Secchi depth (depth, m) | General "water quality", water transparency |

*Table 2: SWOS Indicators on Water Quality and its usability for ecosystem condition mapping*

A water quality algorithm applied to remote sensing data can provide accurate estimates of these water quality parameters if the optically active substances, e.g. Chlorophyll a, in the water body correspond well to the conditions that the algorithm was developed for. Hence, the generated Chlorophyll a (Chl a), suspended sediments (TSM), coloured dissolved organic matter (CDOM) and Secchi depth (SD) products will correspond to absolute or relative estimates of each parameter depending on how well the applied algorithm is adapted to the properties of the water body under investigation. The listed sub-indicators are also mentioned as indicators of eutrophication, physical disturbance, and contamination and general "water quality", respectively. For example, increasing levels of Chl a concentrations serves as an index for increasing level of nutrients and potential eutrophication of a water body. Additionally, high levels of Chl a concentrations serve as an index for high phytoplankton biomass, which often indicate poor water quality, and in a second step poor aquatic biodiversity.

The retrieval of Chl a, TSM and CDOM products was based on the Case-2 water Properties Processor from Free University of Berlin (FUB/WeW) (Schroeder et al. 2007a; Schroeder, Schaale and Fischer 2007b). The initial daily products were aggregated to monthly products corresponding to arithmetic means for all available valid pixels within each calendar month between June 2002 and April 2012 (the life span of the MERIS sensor). A number of different algorithms for retrieval of Secchi Depth have been applied to the data, but a selection on best approach has not been made and the product is not yet routinely included as a SWOS water quality (WQ) product. In, general, water quality products are being produced for lakes/open water surfaces of a minimum of approximately 3 km² of open water (where the depth exceeds the Secchi depth) within or adjacent to a number of SWOS wetland sites. Based on these products water quality status maps corresponding to the Sub-indicators 7.1-7.3 (7.4) are derived and will be published on the SWOS portal[3].

To date, WQ monthly average products corresponding to the sub-indicators listed above have been produced for several SWOS sites and within some Ecopotential project additional sites (Lakes Prespa and Ohrid, as part of the collaboration between both projects) where the abovementioned conditions are met. Validation, in terms of comparison between available in situ data and MERIS derived sub-indicators, are performed, but in most sites it is very limited due to the scarce availability of in situ data.

For acquisition dates post 2012 processing methodologies will be tested on Sentinel-3, Sentinel-2 and Landsat 8 data.

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[3] http://portal.swos-service.eu/mapviewer/detail/1.html

## 5.4. Ecosystem services indicators

Ecosystem service indicators are an important tool to assess and map the degree of provision of specific ecosystem services. The level of provision of ecosystem services is an indicator for the degree of ecosystem health. In turn, the importance of protecting and preserving a good condition of wetland ecosystems should be highlighted, to enable the high supply of the "maintenance of nursery populations and habitats" ecosystem service.

Within the context of SWOS, so far three ecosystem service indicators are being developed: The first and more advanced indicator is the **flood regulation capacity** of wetland ecosystems. The second wetland ecosystem service developed by SWOS is the **maintenance of nursery populations and habitats**, whereas the third indicator on c**arbon stock** is still under development and will not be included at this stage in this document (expected to be published early 2018).

### 5.4.1. Flood regulation capacity

| Indicator | Flood regulation capacity |
|---|---|
| Purpose | Identification of important areas of a river basin for restoration and conservation. |
| Satellite images | Sentinel-2, Landsat series |
| Frequency | Yearly |
| Scale/Resolution | 10 meters (S2), 30m (Landsat) |

The **flood regulation capacity** indicator is an evidence based approach to understand the variables that contribute to the generation of floods and the socioeconomic components that are most affected by them and their location in a river basin indicates and provides a proxy to assess wetland ecosystem condition in terms of its capacity to regulate floods. The results of the indicator prove to be useful to support the identification of important areas to support European targets such as the EU Biodiversity Strategy to 2020 (and the MAES WG focusing on Target 2 Action 5) by prioritising areas to support restoration targets through the implementation of nature-based solutions to degraded wetland ecosystems.

The approach is developed at basin level using information on the environmental factors such as precipitation, slope, soil, and vegetation cover, LULC to model the runoff water generated by extreme precipitation events and to assess the capacity of the land to supply regulation service. The demand for the service is assessed by the analysis of the exposure and vulnerability of people and assets within flood-prone areas taking into account the social and economic value of the assets exposed the human vulnerability, and the spatio-temporal flood characteristics. The use of this indicator helps identifying sites of accumulation of runoff and areas prone to high speed water flow in situation of high/ torrential rainfalls. The location of these sights supports stakeholders for planning purposes in terms of mitigation to the effects of extreme runoff; 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 results are service supply maps (Figure 5) that assess the condition of the flood regulation service within a river basin. They identify zones of high capacity to supply the service if properly protected and managed. On the other hand, the maps also help the detection of areas with a low service provision where measures can be taken to improve it. With the help of the input data that have been used for calculating the supply indicator, such as the layer with the curved number values or the percentage of rain transformed into runoff, this indicator locates the areas that contribute most to the floods as priority areas for restoration as nature-based solutions in the mitigation of floods.

Figure 5 shows an example of the identification of areas for the implementation of measures of protection and restoration of the flood regulation ecosystem service. Yellow circles show natural areas that provide a good service of flood regulation, as areas where protection and proper management is a priority. On the other hand, red circles show large cultivated area with high runoff generation where ecological restoration could be applied to improve the service supply capacity.
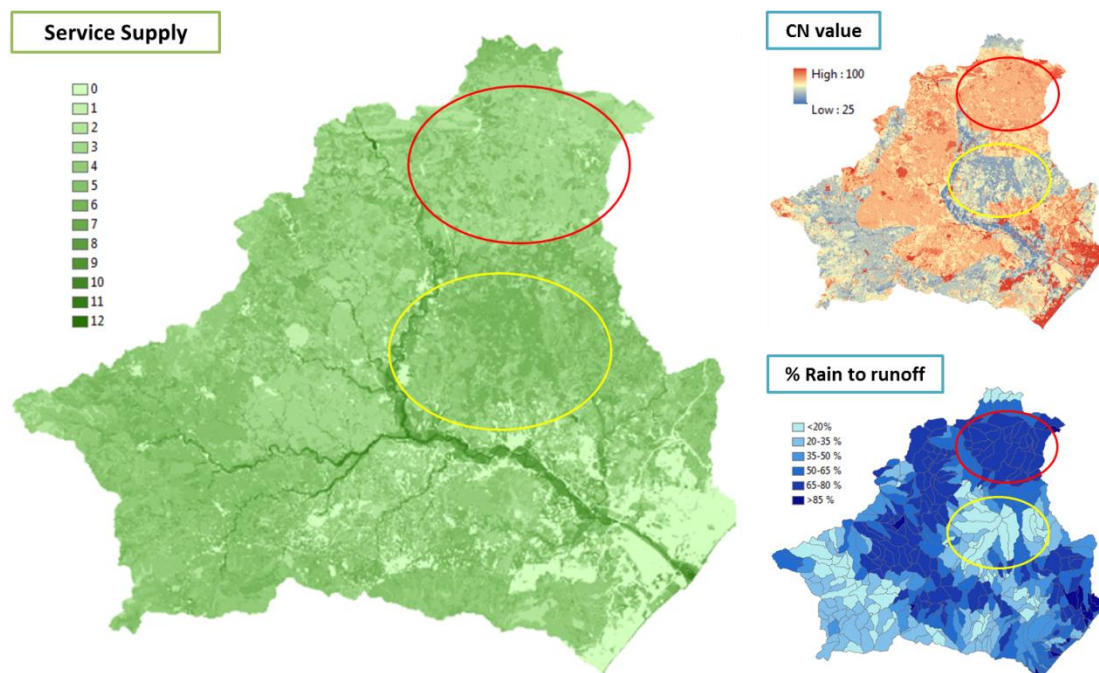


*Figure 5. Guadalhorce river, Spain. Service supply map and identification of areas for flood regulation service protection and restoration*

### 5.4.2. Maintenance of nursery populations and habitats

| Indicator | Maintenance of nursery populations and habitats |
|---|---|
| Purpose | Assess wetland ecosystems' condition in terms of their capacity to function as corridors for migration, dispersal and genetic exchange of wild species |
| Satellite images | Sentinel-2, Landsat series (for mapping landscape heterogeneity) |
| Frequency | Yearly |
| Scale/Resolution | 10 meters (S2), 30m (Landsat) |

Wetlands are important ecosystem for wild fauna and flora hosting a range of habitats and species of European Community interest (Article 10 of the Habitats Directive). They function as corridors for migration, dispersal and genetic exchange of wild species and need to be conserved as key landscapes for enhancing the coherence, connectivity and resilience of the broader protected area network (Article 4 of the Birds Directive). According to Maes et al. (2014), currently there is no available indicator for assessing the "maintaining nursery populations and habitats" provided from wetland ecosystems. The proposed SWOS work targets to fill this gap, by developing a relevant indicator to assess the capacity of wetland ecosystems to **maintain nursery populations and habitats.**

The landscape, as an integrated system, can be seen as a mosaic of natural and semi-natural ecosystems (conservation objective), offering the most favourable habitats for species movement and dispersal, and of urban and high human induced ecosystems (i.e. intensive agriculture), which offer the most hostile habitats. Further, existing conservation networks (i.e. Natura 2000 network, CDDA) require for establishing the necessary functional connections inside and outside the designated sites at the wider landscape level where the connectivity of wetland ecosystems outside protected areas (usually small to medium sized areas), plays a key role for the supply of nursery ecosystem service.

According to the Burkhard et al. (2014), ecosystem service assessment is based on the ecosystem function, ecosystem service supply and demand. The ecosystem function is referred to the idea that ecosystems provide a certain potential to supply services based on their functioning (van Oudenhoven et al., 2012). Ecosystem service supply is referred to the full potential of the ecosystems to provide services and reflects their current condition and capacity whereas ecosystem service demand is directly linked to a specific user need and benefits (Erhard et al., 2016).

SWOS proposes a methodological approach for assessing the role that wetland ecosystems can play to activate the nursery service at the wider context of landscapes (i.e. catchment areas, sub-national territories, regions, EU) (Figure 6), adapting the framework by Burkhard et al. (2014) to the case of the assessment of the "maintenance of nursery populations and habitats" ecosystem service provided by wetland ecosystems
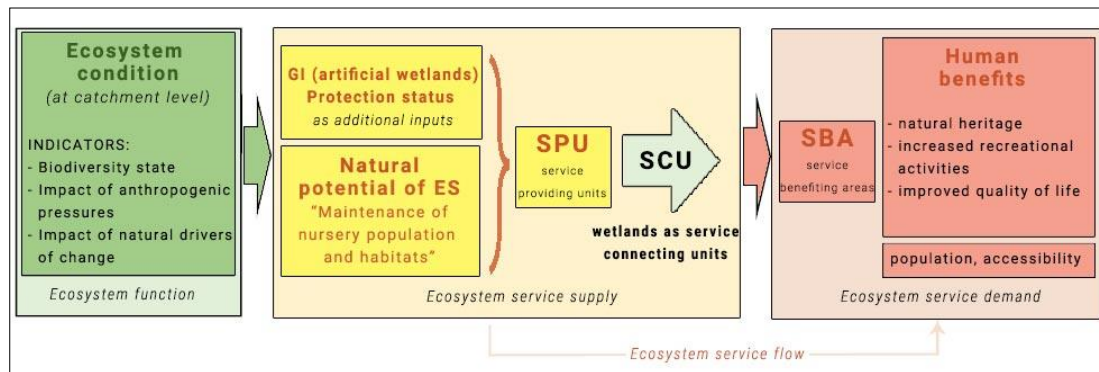
*Figure 6. Conceptual framework of the assessment of the "maintenance of nursery populations and habitats" ecosystem service (Adapted from Burkhard et al., 2014).*

In particular, heterogeneity and biotic diversity are the two components of ecosystem functioning/integrity that are integrated into the assessment of the ecosystem condition along with the impacts of anthropogenic pressures. The landscape heterogeneity is assessed applying the MAES ecosystem typology as modified by SWOS (Fitoka et al., 2016). The typology offers the adequate basis for aggregating the landscape into broad categories of favourable and hostile areas for biodiversity maintenance.

The natural potential of the landscape's ecosystems is assessed, from high to low, reflecting ecosystem condition. Two additional parameters can act together with the natural potential to activate higher service supply and indicate the landscape units that provide the 'nursery' ecosystem service (SPU). These parameters (additional inputs) represent human interventions with a conservation target: the existence/establishment of protected areas and of human made wetlands (i.e. artificial urban lakes). Their selection is based on the concept that wetlands are recognized as Green Infrastructures and promoted to be integrated into coastal protection, improvement of urban environments etc.

As a final step, wetland ecosystems are assessed as "service connecting units" (SCU) that may found in landscape units with high or even low natural potential and affect accordingly, the 'nursery' ecosystem service (i.e. by connecting Natura 2000 sites) and the benefits that humans can have from nature conservation i.e. recreational opportunities, improved quality of life, the natural heritage itself. Wetland ecosystems that can be identified as SCU, are usually those that are of small to medium size (generally below 8 ha) and are located outside the protected networks (i.e. Natura 2000 network). For example, the assessment may identify wetlands that support service flow from hotspots of SPU to hotspots of service benefiting areas (SBAs), or wetlands that although are located at SPUs with no or low service supply, they have significant role as green infrastructures.

Such an assessment can enable several ecosystem service supply scenarios that are essential for decision making in order to advance conservation measures into policy, in line with the DPSIR (Drivers, Pressures, State, Impact and Response) framework. Scenarios can also help understanding the degree of rivalry that indicates how much the use of the service by one user group (i.e. visitors of natural areas) impacts the quality or quantity of the service available to natural heritage itself or to other user groups (e.g. researchers, students, food consumers, etc.).

Conclusively, the proposed assessment of the wetland ecosystems role to activate the supply of "maintenance of nursery populations and habitats" ecosystem service, is taking into account the following:

- The Ecosystem Condition

- The Ecosystem Potential to supply ES

- The Ecosystem Service Demand

- The spatial relationships between the SPU, SCU and SBA

The assessment of ecosystem condition refers to the analysis of the major pressures on ecosystems and the impact of these pressures on the condition of ecosystems in terms of the health of species, the condition of habitats and other factors including soil, air and water quality. If impacts or condition cannot be quantified, the pressures are also used as indicators of ecosystem condition (Erhard et al. 2016).

To assess ecosystem condition, either qualitative or quantitative analysis needs to be made using a variety of indicators. Ideally, these indicators should represent key information on the biodiversity structure and functions and on the presence of natural and anthropogenic drivers of change that cause ecosystems degradation. For the assessment in the context of SWOS, three condition indicators are proposed: Biodiversity State Indicator (BS), Impact of Anthropogenic Pressures Indicator (IAP) and Exposure to Drought (ED), including a variety of variables such as

- conservation status of habitat types;
- population trends of breeding birds;
- breeding range trends of breeding birds;
- diversity of habitat types, flora and fauna species and breeding birds;
- distribution pattern of the habitat/species;
- degree of the landscape mosaic degradation;
- degree of imperviousness;
- the population density;
- the threats to biodiversity as these were reported in the national reports under Art. 17 and Art. 12 of the Habitats and Birds Directives respectively and
- the Drought Vulnerability Index (DVI).

The results of the application of this conceptual framework in the SWOS test area of the Attica Region of Greece are expected at the end of 2017.

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