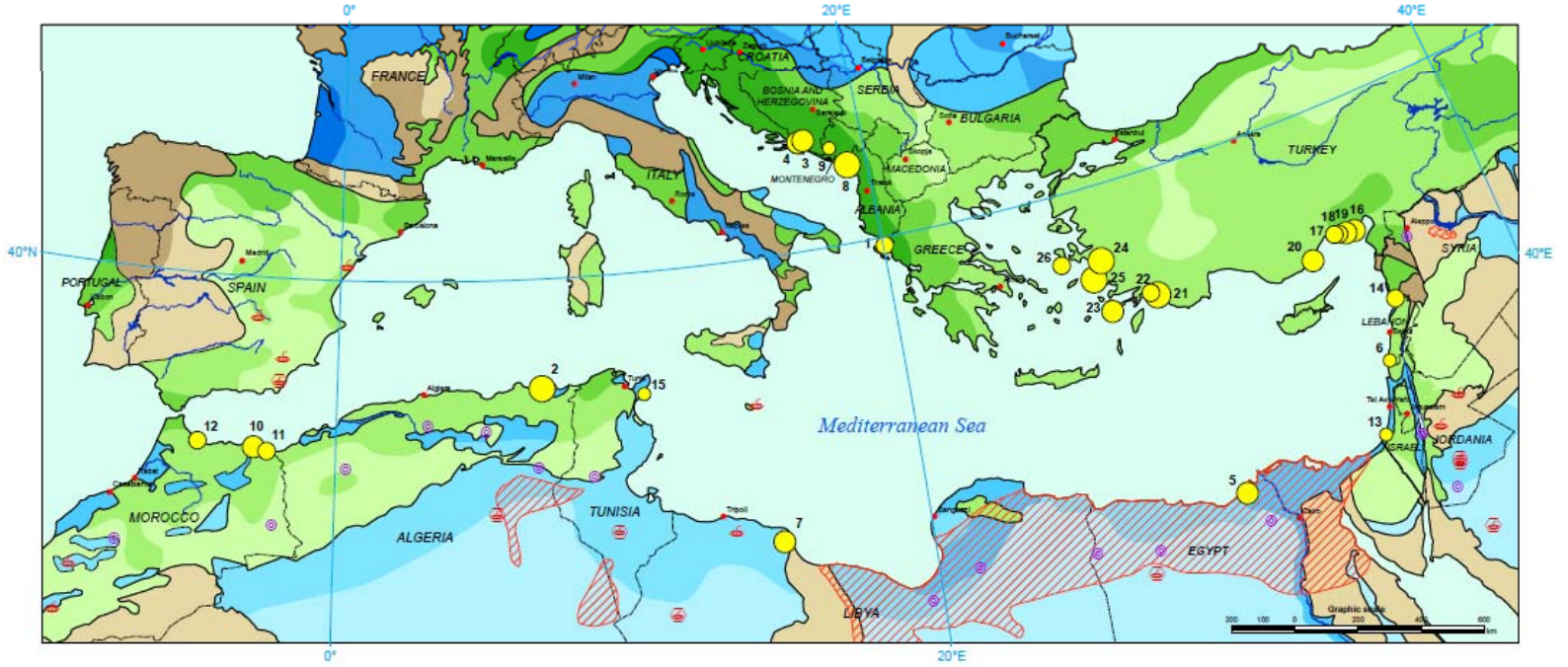
Instituto Geológico y Minero de España (IGME)

Hydrogeological and ecosystem services classification of representative Mediterranean coastal groundwater-related wetlands

Map of selected wetlands in the Mediterranean area.

Map Explanation

October 2015



MedPartnership

Instituto Geológico y Minero de España

UNIVERSITAT POLITÈCNICA DE CATALUNYA

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FRONT COVER

Location of selected wetlands evaluated in the activity *Implementation of eco-hydrogeology applications for management and protection of coastal wetlands,* executed by UNESCO-IHP within the frame of the component on Management of Coastal Aquifers and Groundwater of the GEF/UNEP-MAP project Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem (MedPartnership), with the background of the hydrogeological map (kindly provided by WhyMap Programme).

Hydrogeological and ecosystem services classification of representative Mediterranean coastal groundwater-related wetlands

Map of selected wetlands in the Mediterranean coast

Map Explanation

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October 2015

About IGME

The Instituto Geológico y Minero de España (IGME) is a public research organisation.
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1. Introduction

1.1 Background

The map on *Hydrogeological and ecosystem services classification of representative Mediterranean groundwater-related wetlands*, and this Map Explanation, are among the products of the activity "*Implementation of eco-hydrogeology applications for management and protection of coastal wetlands*", which is part of the Sub-component 1.1 "*Management of Coastal Aquifers and Groundwater*" of the project Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem (MedPartnership). The Sub-component 1.1 has been led by UNESCO-IHP between years 2009 and 2015 with the participation of the Mediterranean countries where the MedPartnership project is being carried out, and of several research and management institutions from other European countries. The MedPartnership countries are: Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Lebanon, Libya, Montenegro, Morocco, Palestine, Syria, Tunisia and Turkey.

The scientific work performed in the activity "*Implementation of eco-hydrogeology applications for management and protection of coastal wetlands*" involved three main tasks which generated differentiated products:

Task 1: Elaboration of a Regional Report (RR) titled *Management and protection of Mediterranean groundwater-related coastal wetlands and their services* (UNEP-MAP UNESCO-IHP, 2015a). The RR includes chapters addressing basic conceptual and practical aspects to be considered for the efficient management of groundwater-related coastal wetlands and their services; Country Reports on 26 coastal wetlands from the MedPartnership countries, and guidelines and recommendations for the evaluation and integrated management of groundwater related coastal wetlands. The Country Reports contain information extracted from three excel sheet forms arranged to collect adequate information on coastal wetlands, their ecosystem services, and the drivers of change of wetlands functioning factors. Three synthetic sheet forms compiling the 26 original, country-based sheets received are also included in an annex of the RR. Both the Country Reports and the excel sheet forms were designed and prepared for this project by experts of the Technical University of Cartagena (UPCT, Spain) and the Technical University of Catalonia (UPC, Spain). The rest of the RR benefited from the contribution of experts from several other European institutions.

Task 2: Elaboration of a Technical Report (TR) titled *Main hydro(geo)logical characteristics, ecosystem services, and drivers of change of 26 representative*

Mediterranean groundwater-related coastal wetlands (UNEP-MAP UNESCO-IHP, 2015b). This report encompass the main results attained after elaboration of the hydrogeological, ecosystem services and drivers of change information compiled in the excel sheet forms mentioned above. The work was carried out by experts of the UPCT, with collaboration of experts from the UPC, the University of Valencia (UV, Spain), and Geological and Mining Institute of Spain (IGME).

Task 3: Elaboration of a Map, and a Map Explanation, on *Hydrogeological and ecosystem services classification of representative Mediterranean groundwater-related wetlands*. The map display information on the 26 coastal wetlands reported in task 1. The information used to perform wetlands classification and ecosystem services assessment has been obtained from the sheet forms prepared for Task 1.

Tasks 1 and 2 have been coordinated by UNESCO-IHP and the UPCT, with the support of UPC, UV and IGME. Task 3 has been coordinated by IGME, with support of the UPCT.

The IGME received the commitment of:

a) Developing a two sided electronic map of a selected number of groundwater-related coastal wetlands in the Mediterranean region, taking advantage of the design that IGME previously demonstrated for the mapping of Ramsar sites in Spain (Durán et al., 2003; 2005), and of the experience of UPCT, UPC and UV experts participating in tasks 1 and 2 on wetlands hydrogeology, wetlands classification, and assessment of ecological services in wetlands (DGOH, 1991; Custodio, 2000; Manzano et al., 2002; PAH, 2004; EME, 2011, 2014).

b) Preparing this Map Explanation, with the collaboration of the scientific committee of tasks 1 and 2, and the MedPartnership Country Experts.

1.2 The goal

The aim of the Map is to provide a hydrogeological classification methodology for coastal Mediterranean wetlands linked to groundwater, and a graphic representation system of both the wetlands hydrogeological background and the status and evolution trends of the ecosystem services provided by those wetlands. The ultimate goal is to generate an easy to display and to understand tool to strengthen the capacity of water management institutions in the Mediterranean region to identify wetlands typologies, functionality conditions, services provided to wellbeing, and their status and observed evolution trends.

All this information is required to implement sustainable management and protection programs of coastal wetlands and the related groundwater resources.

1.3 The wetlands

As mentioned in Section 1.1, the wetlands included in the map are those previously reported for Task 1 of the UNESCO-IHP activity "*Implementation of eco-hydrogeology applications for management and protection of coastal wetlands*". Those wetlands were chosen according to the following criteria:

- Coastal wetlands related to groundwater at any degree.
- Well know wetlands, with enough information to allow obtaining a hydrogeological and ecosystem services classification according to the methodology presented in Section 4.

The location of the wetlands considered in the map can be seen in Figure 1, and their names and countries are shown in Table 1.

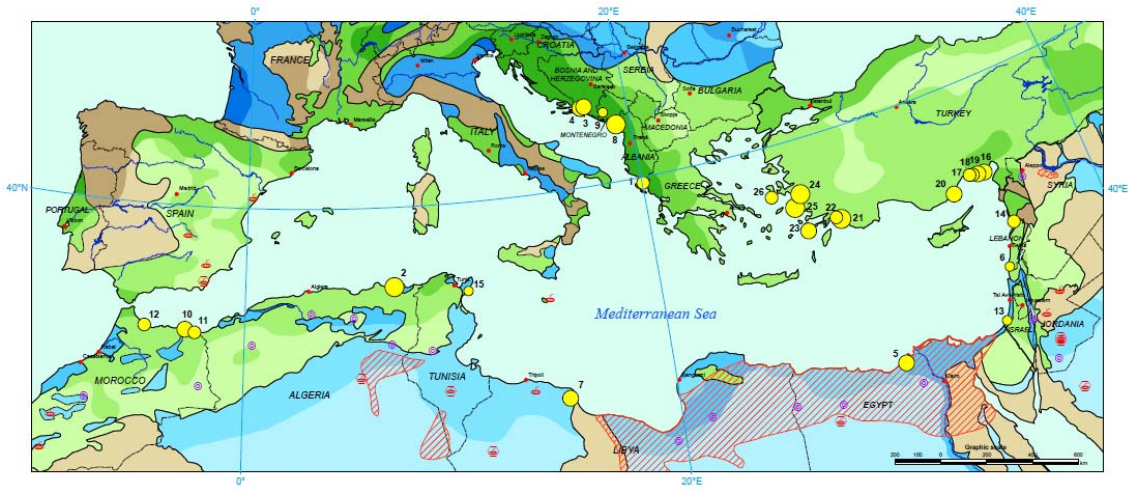


Figure 1. Coastal wetlands considered in the map of *Hydrogeological and ecosystem services classification of representative Mediterranean groundwater-related wetlands*. The size of the yellow circles is proportional to the wetland size (see details in Section 3.1).

Table 1. List of wetlands included in the map of *Hydrogeological and ecosystem services classification of representative Mediterranean groundwater-related wetlands*. Numbers refer to the identification of the wetlands in the map.

Nr.	Wetland Name	Country
1	Butrinti Lake	Albania
2	Guerbes-Sanhadja	Algeria
3	Hutovo Blato	Bosnia & Herzegovina
4	Neretva Delta	Croatia
5	Mariut Lake	Egypt
6	Tyre Beach	Lebanon
7	Tawurgha Spring	Libya
8	Skadarsko Lake	Montenegro
9	Tivatska Solila	Montenegro
10	Bou Areg Lagoon	Morocco
11	Oued Moulouya Estuary	Morocco
12	Oued Laou Estuary	Morocco
13	Wadi Gaza	Palestine Territory
14	Akkar Plain	Syria
15	Korba (Cap Bon) Lagoon	Tunisia
16	Yumurtalik Lagoon	Turkey
17	Akyatan Lagoon	Turkey
18	Tuzla Lagoon	Turkey
19	Dipsiz Wetland	Turkey
20	Göksu Delta	Turkey
21	Dalaman Wetlands	Turkey
22	Dalyan Wetlands	Turkey
23	Büyük Memderes Delta	Turkey
24	Küçük Menderes Delta	Turkey
25	Gediz Delta	Turkey
26	Gökçeada Lagoon	Turkey

2. Information sources

The map includes three types of information:

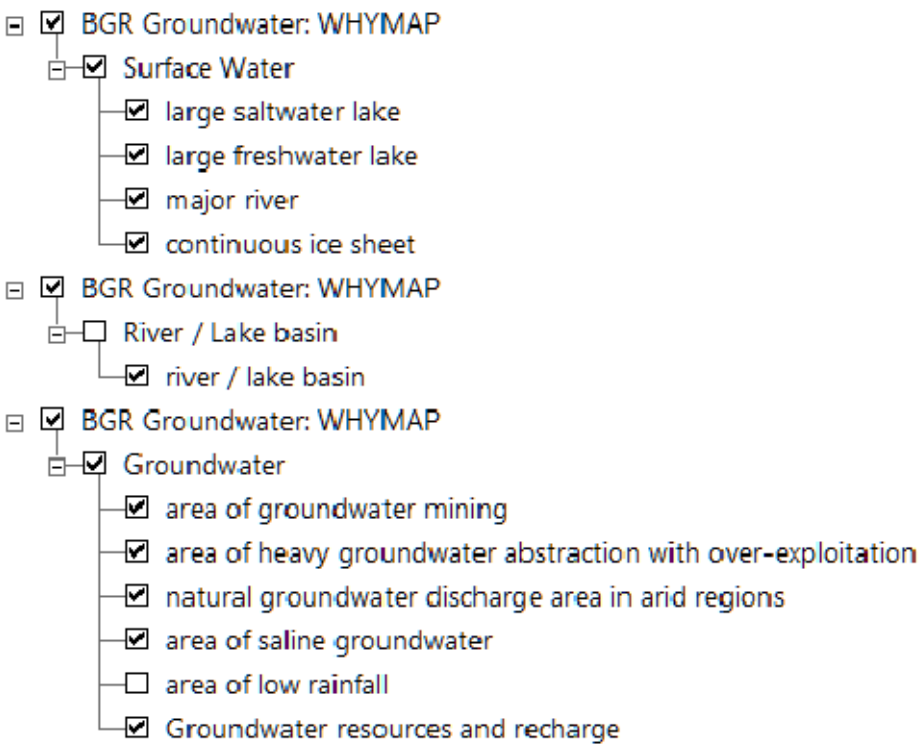
a) A hydrogeological background map, which has been provided by BGR as shape files. Its source is the WhyMap programme, which is available at the site www.whymap.org.

b) A picture of each one of the 26 wetlands displayed. The pictures have been provided by the Country Experts from the MedPartnership project participating in the UNESCO-IHP activity "*Implementation of eco-hydrogeology applications for management and protection of coastal wetlands*".

c) Three graphics for each wetland, showing the following information: i) the hydrogeological classification of each wetland, after the classification system designed for this product by some of the map authors; ii) the status of performance of a set of pre-selected ecosystem services; iii) the observed (or forecasted) evolution trend of those ecosystem services (see more details in Section 3). All the graphics have been developed for this map by some of the map authors. They have been elaborated using the information reported by the Country Experts in the sheet forms prepared for tasks 1 and 2 of the above mentioned UNESCO-IHP activity (UNEP-MAP and UNESCO-IHP, 2015).

The map production procedure is represented in Figure 2. Basically, it consisted of four phases.

Phase 1: all spatial and alphanumeric information layers needed to generate the background map was collected. The following shapefiles were provided by WhyMap:



Phase 2: ArcGis was used to integrate the former layers and the information related to the location and size of the 26 wetlands shown in the map, as well as the pictures and the different graphics. Both th epictures and the garphics were provided as images files (jpg, tiff, psd, etc.). All these images were converted into one standard format with the size and resolution required by the map design and good quality looking.

Phase 3: the map was prepared through the application of different softwares in order to look for the best quality result. The preliminary layers created in ArcGis were later worked through Adobe Illustrator and Corel Draw, due to the better tools for editing graphic information of these design programmes.

Phase 4: elaboration of the final formats:

1) A printable version of the map as pdf file.
2) A set of shapefiles, excel and pdf files ready to be submitted to a geo-referenced information system.

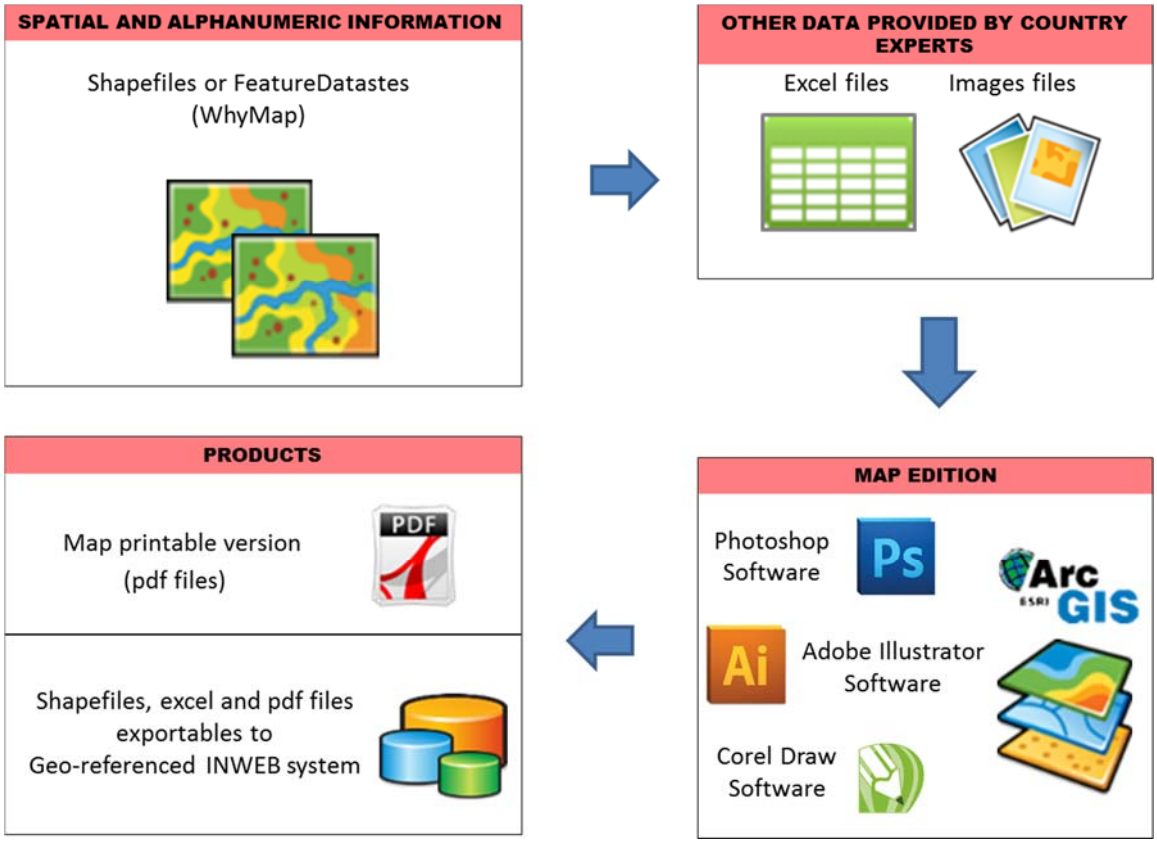


Figure 2. Scheme of map production showing the different steps followed.

The names of the Country Experts which provided wetlands information and pictures are shown in Table 2.

Table 2. List of credits of wetlands pictures and data used in the MedPartnership map.

No.	Wetland Name (Country)	Country Expert
1	Butrinti Lake (Albania)	Emanuela Kiri
2	Guerbes-Sanhadja (Algeria)	Larbi Djabri
3	Hutovo Blato (Bosnia & Herzegovina)	Zoran Mateljak
4	Neretva Delta (Croatia)	Ognjen Bonacci
5	Mariut Lake (Egypt)	Amr Fadl
6	Tyre Beach (Lebanon)	Amin Shaban
7	Tawurgha Spring (Libya)	Omar Salem
8	Skadarsko Lake (Montenegro)	Dragan Radojevic
9	Tivatska Solila (Montenegro)	Dragan Radojevic
10	Bou Areg Lagoon (Morocco)	Nour-Eddine Laftouhi
11	Oued Moulouya Estuary (Morocco)	Nour-Eddine Laftouhi
12	Oued Laou Estuary (Morocco)	Nour-Eddine Laftouhi/Mbarek Boumaaza GREPOM
13	Wadi Gaza (Palestina)	Khalid Qahman
14	Akkar Plain (Syria)	Abdullah Droubi
15	Korba (Cap Bon) Lagoon (Tunisia)	Noureddine Gaaloul / Kamel Zouari
16	Yumurtalik Lagoon (Turkey)	Serdar Bayari / O. Erdem
17	Akyatan Lagoon (Turkey)	Serdar Bayari / M. Cevirgen

18	Tuzla Lagoon (Turkey)	Serdar Bayari / O. Erdem
19	Dipsiz Wetland (Turkey)	Serdar Bayari / TRWL Authority
20	Göksu Delta (Turkey)	Serdar Bayari / TRWL Authority
21	Dalaman Wetlands (Turkey)	Serdar Bayari /O. Erdem
22	Dalyan Wetlands (Turkey)	Serdar Bayari / TRWL Authority
23	Büyük Memderes Delta (Turkey)	Serdar Bayari / TRWL Authority
24	Küçük Menderes Delta (Turkey)	Serdar Bayari / TRWL Authority
25	Gediz Delta (Turkey)	Serdar Bayari / O. Bulut
26	Gökçeada Lagoon (Turkey)	Serdar Bayari / TRWL Authority

3. Map legend

3.1 Legend structure

The map legend is divided in two sections (Figure 3). The left section is devoted to the background hydrogeological map. This information was provided by WhyMap and was not modified by IGME; it was just incorporated to the map as background information. The right section of the legend shows the key symbols that represent the size of the wetland, as well as the main contribution of the authors of the map to the MedPartnership project: the hydrogeological classification of each wetland and the evaluation of the wetlands services status and evolution trends. The next epigraphs explain the right part of the legend.

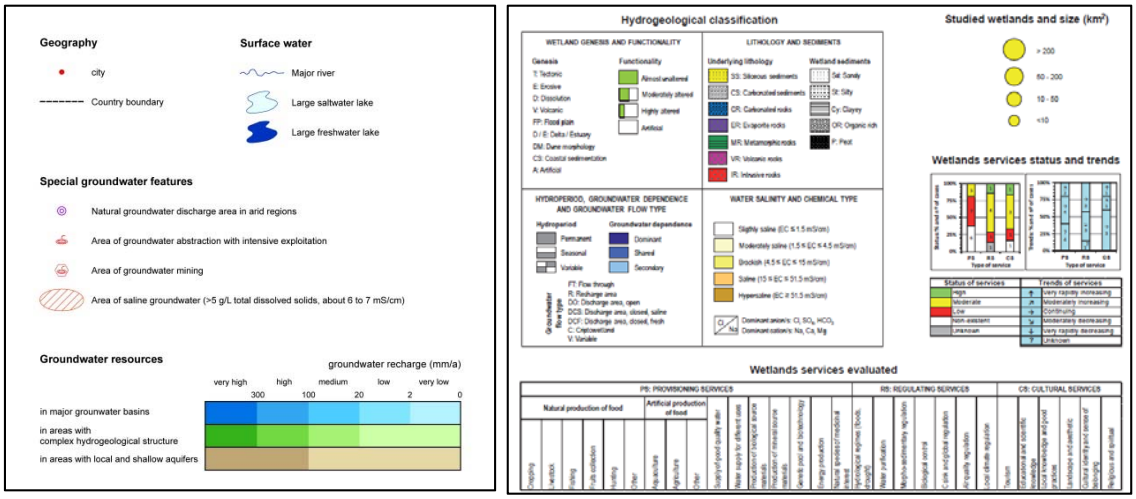


Figure 3. Map legend divided into two sections. Left section preserve the map background received from WhyMap. Right section shows the main contribution of MedPartnership Project: the hydrogeological classification of the wetlands and the status and evolution trends of the ecosystem services of each wetland.

3.2 Wetlands size legend

The surface area of the wetlands is indicated by a yellow circle with different size. The following size ranges have been considered in decreasing order:

Largest circle: > 200 km^2
Next smaller circle: 50-200 km^2
Next smaller circle: 10-50 km^2
Smallest circle: < 10 km^2

3.3 Hydrogeological classification legend

The hydrogeological classification used in this map has been adapted and improved from the methodology used by some of the authors in former works: Study of continental Spanish wetlands. Inventory, classification, relationship with water systems and protection measures (DGOH, 1991; Manzano et al, 2002); Andalusian Wetlands Plan (PAH, 2004); UNESCO Project IGCP 604 “Groundwater and Wetlands in Ibero America” (Bocanegra et al., 2012; Betancur 2013).

This classification pays attention to nine aspects of the wetland:

a) Wetland genesis (Figure 4). The following processes have been considered: tectonic (T), erosive (E), dissolution (D), volcanic (V), flood plain (FP), delta/estuary (D/E), dune morphology (DM), coastal sedimentation (CS), artificial (A).

b) Wetland functionality (Figure 4). Four possibilities have been considered: almost unaltered, moderately altered, highly altered, and artificial.

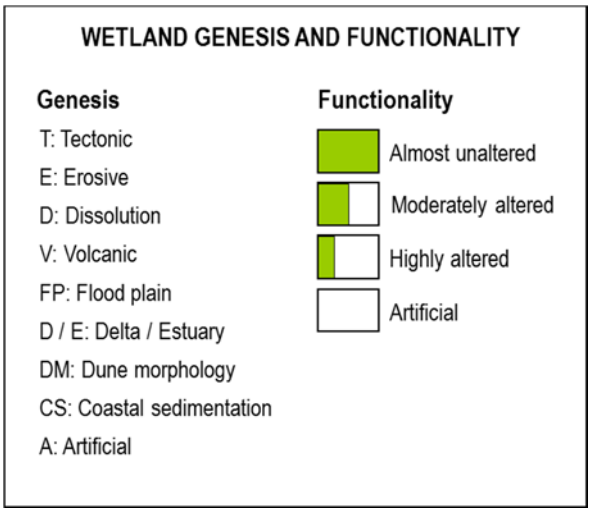


Figure 4. Legend of wetland genesis and functionality (upper left square of the hydrogeological classification graph).

c) Lithology underlying the wetland (Figure 5). The underlying lithology considers the following types of materials: siliceous sediments (SS), carbonated sediments (CS), carbonated rocks (CR), evaporite rocks (ER), metamorphic rocks (MR), volcanic rocks (VR), intrusive rocks (IR).

d) Sediments within the wetlands basin (Figure 5). They can be: sandy (Sd), silty (St), clayey (Cy), organic rich (Or), or peat (P).

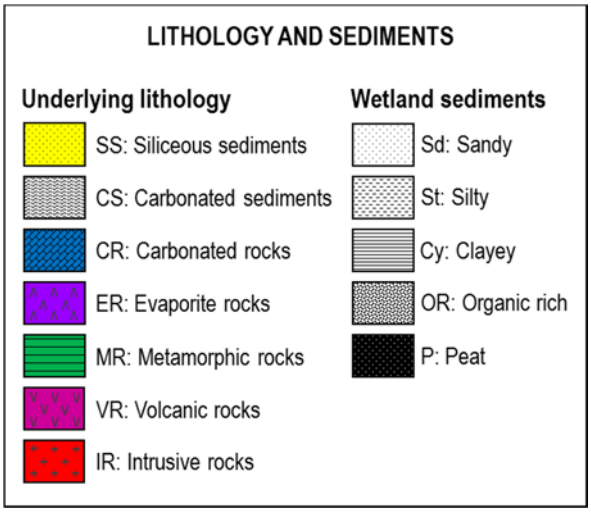


Figure 5. Legend of the underlying lithology and sediments in the wetland basin (upper right square of the hydrogeological classification graph).

d) Hydroperiod (Figure 6). Three possibilities have been considered: permanent, seasonal, and variable.

e) Groundwater dependence (Figure 6). Three possibilities have been considered: dominant, shared, and secondary.

f) Groundwater flow type (Figure 6). The following types have been considered: flow through (FT); recharge area (R); discharge area open (DO); discharge area closed, saline (DCS); discharge area open, fresh (DCF); cryptowetland (C), and variable (V).

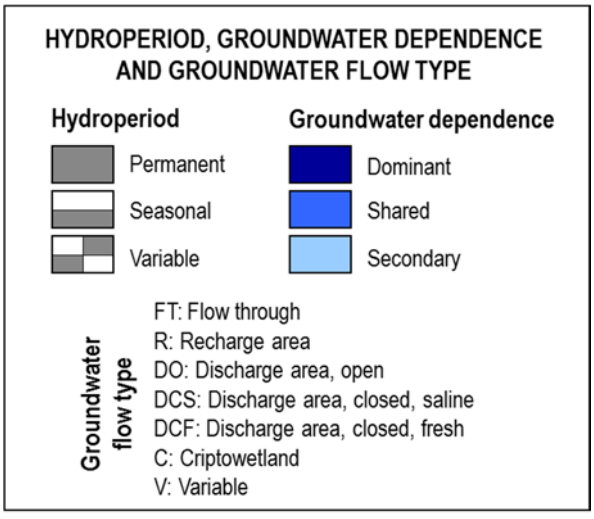


Figure 6. Legend of the hydroperiod, the groundwater dependence and the groundwater flow type (lower left square of the hydrogeological classification graph).

h) Water salinity (Figure 7). Water salinity is evaluated after the electrical conductivity (EC) according to the following ranges:

- Slightly saline (EC < 1.5 mS/cm)
- Moderately saline (1.5 mS/cm < EC< 4.5 mS/cm)
- Brackish (4.5 mS/cm < EC < 15 mS/cm)
- Saline (15 mS/cm < EC < 51.5 mS/cm)
- Hypersaline (EC > 51.5 mS/cm)

i) Chemical type of the wetland water (Figure 7). It is given by the sequence of dominant (> 50 %) major anions (Cl, SO_4, HCO_3) and cations (Na, Ca, Mg) in decreasing order of abundance.

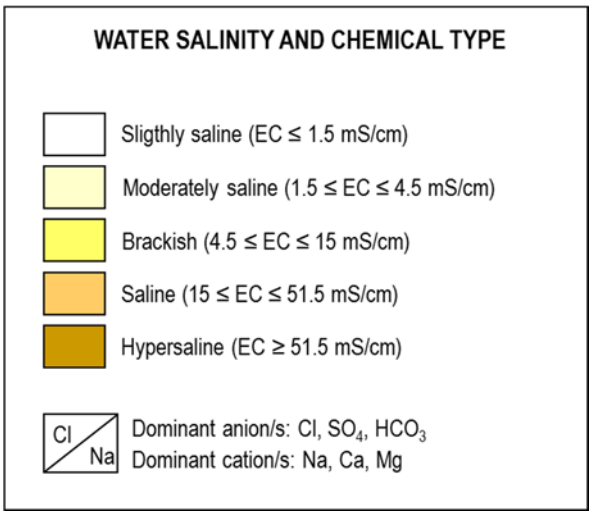


Figure 7. Legend of water salinity and chemical type (lower right square of the hydrogeological classification graph).

These nine aspects are synthesized in a square of four quadrants (Figure 8). a) and b) are shown in the upper left quadrant, c) and d) are shown in the upper right quadrant; e), f) and g) are shown in the lower left quadrant, and h) and i) are shown in the lower right quadrant.

The original data used to perform the hydrogeological classification of each wetland are show on the reverse side of the map, in the table of “General data”. This table has been obtained from UNEP-MAP and UNESCO-IHP (2015a, 2015b).

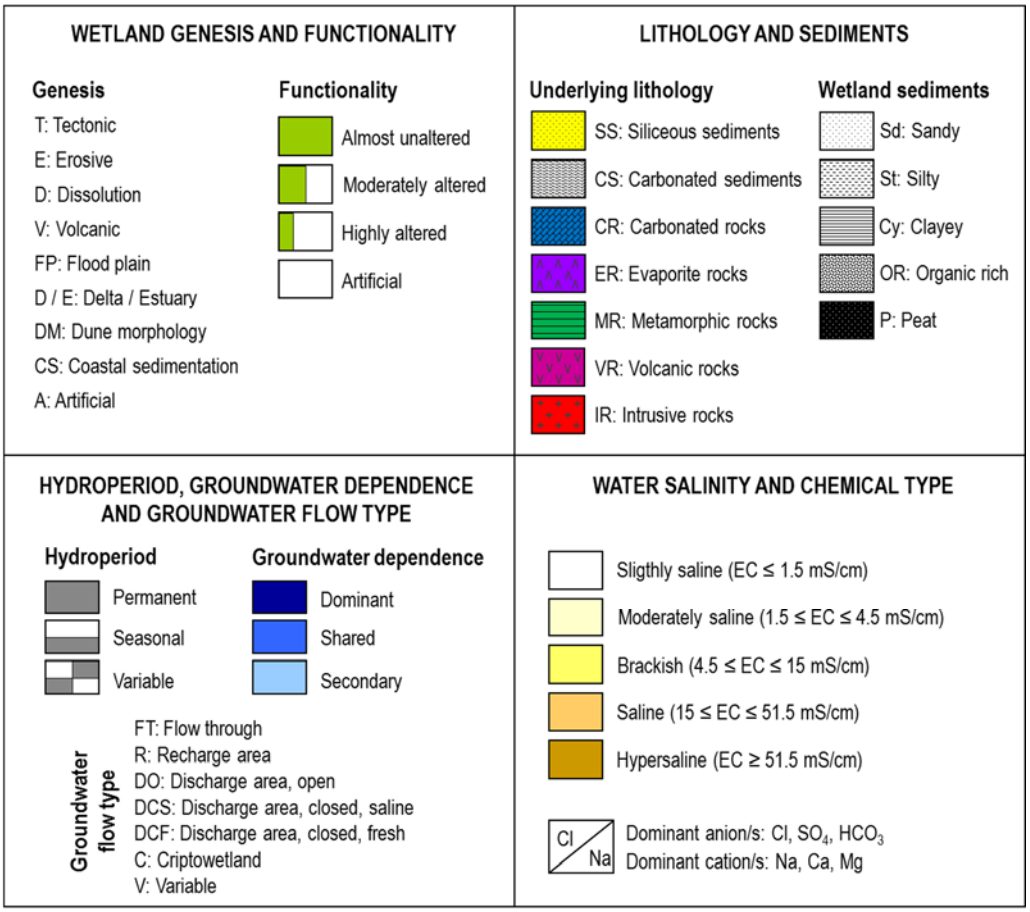


Figure 8. Legend of the hydrogeological classification.

3.4 Wetlands services status and trends legend

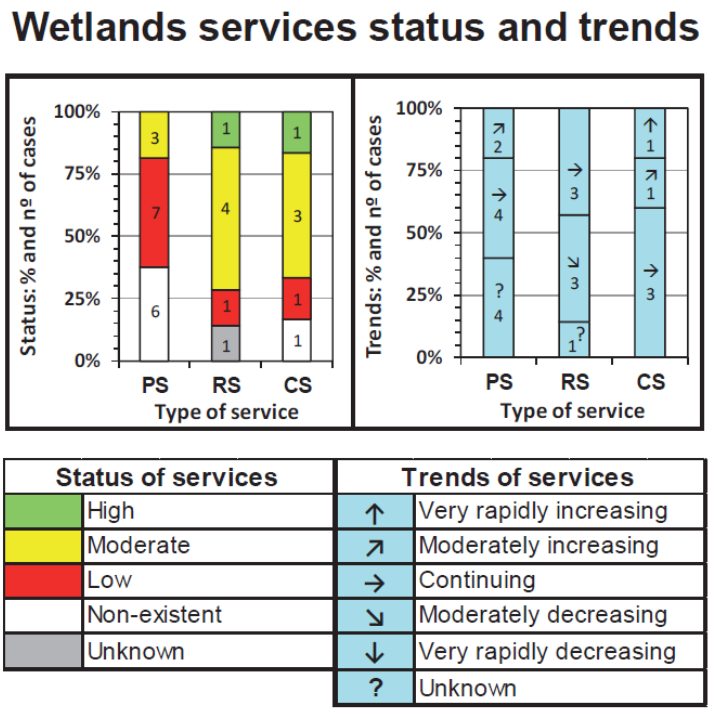
The evaluation of the status of performance and the evolution trends of the services provided by the reported wetlands has been performed in UNEP-MAP and UNESCO-IHP (2015a, 2015b) on the basis of the information provided by the MedPartnership Country Experts. The methodology used to perform the evaluation was the proposed by United Nations in the project Millennium Ecosystems Assessment (MEA, 2005), which had been used by some of the authors of the map in the projects UNESCO IGCP-604 and Spanish Millennium Ecosystems Evaluation (EME, 2011, 2014).

The evaluation methodology is not explained here, as it is not the subject of the map; for full details please address any of the above cited documents. Synthetically, it consist on evaluating the **status** and the observed (or forecasted) evolution **trends** of a set of pre-established services using a code of colors for the status, and a code of arrows for the trends. The status or performance was assessed according to five possible situations: high, moderate, low, non-existing, and unknown. The evolution trends were evaluated according to five possible

situations: very rapidly increasing, moderately increasing, continuing, moderately decreasing, and very rapidly decreasing. Both codes are shown in Figure 9.

Following the proposals of MEA (2005), the set of services evaluated (see more details below) have been grouped into three main categories: Provisioning services (PS), Regulating services (RS) and Cultural services (CS). The wetlands map shows graphically the evaluation results of these three main categories of wetland services for each of the 26 wetlands studied. To do so, two graphs have been designed (Figure 9):

- One graph shows the status of performance of the main categories of services evaluated, PS, RS and CS. The information is shown in two ways: as proportions of services of each main category which are performing at any of the different performance levels considered (with respect to the total number of services within each category; see Y axe), and as concrete number of cases (numbers shown inside de columns).
- A second graph shows the evolution trends reported for each service also in two ways: as proportions of services of each main category which are reported with a particular trend (also with respect to the total number of services within each category; see Y axe), and as concrete number of cases (numbers and arrows shown inside de columns).



Status of services	
	High
	Moderate
	Low
	Non-existent
	Unknown

Trends of services	
↑	Very rapidly increasing
↗	Moderately increasing
→	Continuing
↘	Moderately decreasing
↓	Very rapidly decreasing
?	Unknown

Figure 9. Up: Graphs used in the map to show the status or performance and the evolution trends of the three main categories of services evaluated. Down: Legend used to perform the assessment. (From UNEP-MAP and UNESCO-IHP, 2015a).

The concrete services whose evaluation is presented in the map can be seen in the lower right square of the legend, on the front side of the map. They are (Figure 10):

a) Provisioning services: Natural production of food (cropping, livestock, fishing, fruits collection, hunting, other); artificial production of food (aquaculture, agriculture, other); supply of good quality water; water supply for different uses; production of biologic source materials; production of mineral source materials; genetic pool and biotechnology; energy production.

b) Regulating services: natural species of medical interest; hydrological regimes (floods, droughts); water purification; morpho-sedimentary regulation; biological control; carbon (C) sink and global regulation; air quality regulation; local climate regulation.

c) Cultural services: tourism; education and scientific knowledge; local knowledge and good practices; landscape and aesthetic; cultural identity and sense of belonging; religious and spiritual.

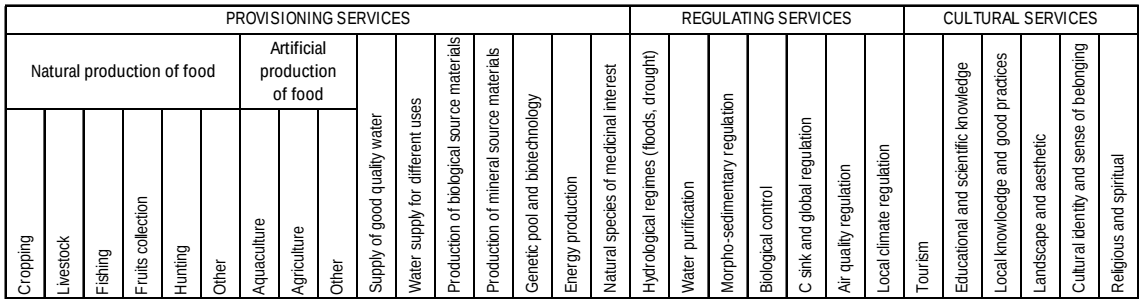


Figure 10. Wetlands services evaluated.

The original data used to perform the graphs of Figure 9 are show on the reverse side of the map, in the table of “Wetlands services contributing to human well-being. Global assessment of status and trends”. It has been obtained from UNEP-MAP and UNESCO-IHP (2015a, 2015b).

3.5 Impact degree and evolution trends of the main drivers of change for the wetlands

Within The UNESCO-IHP activity “*Implementation of eco-hydrogeology applications for management and protection of coastal wetlands*”, the relative impact of the main factors inducing changes in wetlands functioning and in their services (called “drivers of change” in MEA, 2005) have been also evaluated.

Those results are not shown in the front side of the map, but they can be seen on the reverse side, in the table “Main direct drivers of change in wetland systems”, obtained from UNEP-MAP and UNESCO-IHP (2015a, 2015b). Details on drivers of change meaning and evaluation methodology can be seen in those documents. However, some information is provided here in order to facilitate understanding the table.

Forty-four ***drivers of change*** to wetland systems have been considered, which have been grouped into seven main categories:

1. Resource exploitation (referring to the degree of sustainability related to the maintenance or not of the ecological integrity of the wetland because of its exploitation). Three main resources have been considered: water, biological materials, and mineral materials. Each of them has been split into four to five different and concrete situation.
2. Changes in land use (altering the capacity of maintenance of ecological health or causing ecosystem loss). Nine particular drivers have been considered: deforestation, reforestation, forest management, replacement of species, extensive agriculture, extensive cattle raising, urbanization, roads, others.
3. Modification of the hydrological cycle (causing hydrological changes compared to the natural regime in terms of water amount). Six particular drivers have been considered: drainage, input of excess irrigation water, storage usage, artificial recharge, input of urban wastewater, others.
4. Pollution (causing changes in the physical, chemical and/or biological quality of wetland water, sediments and/or biota). Three particular drivers have been considered: agricultural diffuse pollution, atmospheric diffuse pollution, urban or industrial point source pollution.
5. Alteration of biological community structure and ecosystem functioning (causing changes in the provision of any kind of ecosystem services). Four particular drivers have been considered: invasive exotic species, native species extinction, alteration of biogeochemical cycles, fragmentation.
6. Effects associated with changes (occurrence of these effects resulting from the existence of other drivers). Five particular drivers have been considered: changes of chemical water quality, changes of biological water quality, oxidation by lowering the water table, increased erosion, soil destruction.
7. Global and climate changes (changes in the pattern of these drivers). Three particular drivers have been considered: rainfall, temperature, sea level rise.

As for the evaluation of ecosystem services, a code based on colors and arrows (based in MEA, 2005, and EME, 2011, 2014) have been used to evaluate the impact degree of each particular driver of change and its observed (or forecasted) evolution trend in each wetland (Figure 11).

Impact of drivers		Trends of drivers	
	High	↑	Very rapidly increasing
	Moderate	↗	Moderately increasing
	Low	→	Continuing
	Non-existent	↘	Moderately decreasing
	Unknown	↓	Very rapidly decreasing

Figure 11. Legend used to evaluate the *drivers of change* considered in the *Table of main drivers of change* on the reverse side of the map. (From UNEP-MAP and UNESCO-IHP, 2015a).

References

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