SERVICIOS DE MAPES EN LÍNIA (WMS) DERIVADOS DE LA BASE DE DATOS DE INFORMACIÓN GEOLÓGICA Y GEOFÍSICA DEL DELTA DEL EBRO

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0 Foreword

The project LIFE EBRO-ADMICLIM puts forwards pilot actions for adaptation to and mitigation of climate change in the Ebro Delta (Catalonia, Spain), an area vulnerable to sea level rise and subsidence.

The project aims to achieve these results through an action entitled *Assessment of areas vulnerable to subsidence and sea-level rise in the Ebro Delta (implementation action B.6 of the project).* Products of this action are expected to be public as a Web Map Service which is one of the deliverables of the action B6.

1 Introduction

Throughout the Action B6 development, geological and geophysical information and data has been generated and collected. In order to manage and publish this information, it was established the use of opensource software though a Postgres / PostGIS v.10.0 Database manager.

2 Web Map Service (WMS)

To allow an organized access to this information, a Web map Service (WMS) was created. In this service the stored data is published using layers of information with a specific symbology and accessed through queries to the main features of the published layers. The WMS Service was created through Geoserver v.2.9.0 open source server, following the standards of the Open Geospatial Consortium (OGC).

In order to visualize the information of the WMS service, it should be loaded though URL into a GIS software such as QGIS or ArcGIS. The URL of the service is:

`http://geoserveis.icgc.cat/icgc_lifeebro/wms/service`?

The main technical characteristics of the WMS service are:

- OGC supported: WMS 1.0.0, 1.1.0, 1.1.1, 1.3.0
- EPSG original: 25831
- EPSG supported: 3034, 3035, 3043, 3857, 4258, 4326, 25831, 32631
- GetMap supported formats: GIF, PNG, BMP, JPEG, TIFF, SVG+XML
- OGC supported methods: GetCapabilities, GetMap, GetFeatureInfo, GetLegendGraphic

The WMS service has a total of 62 terrain attributes distributed in layers where which both, vector and raster information, is included. The data range of visualization minimum scale was set at 1: 3 000 000 to optimize the service response.

3 Layers

The diffent layer’s description, simbology and attributes are as it follows.

3.1 Shoreline

The Ebro delta is an active sedimentary body which is the result of the interaction of the Ebro River sedimentary processes and the Mediterranean sea marine dynamics. For this reason its shoreline is not fixed and changes with time, depending the most dominant process. Most of the maps and information developed during the Life EBRO-ADMICLIM project considered the shoreline of the ICGC 1:50.000 topographic map

(2011). This consideration aims to keep spatial consistency to the map. Hence the used coastline present some changes compared with the available shorelines of the Ebro Delta plain. For each layer you can access to the year of the shoreline as an attribute.

	Shoreline Topographic base 1:50.000
	Shoreline in 2017
	Shoreline in 2014
	Shoreline in 2005
	Shoreline in 1993
	Shoreline in 1983
	Shoreline in 1974
	Shoreline in 1956
	Shoreline in 1945
	Shoreline in 1923

3.2 Soil map ofthe Ebro Delta plain

Distribution of the Ebro Delta plain's soil units. As attributes we can access to the soil unit and USDA and FAO soil classification.

	S1
	S2
	S3
	S4
	S5

3.3 Aproximated distribution of marshes around 1880

From the second half of the 19th century, level of detail and precision of cartographic documentation increases, allowing a more exhaustive analysis of the morphological evolution of the Ebro Delta plain through its georeferencing. Based on the projection of the 19th century maps, some of the most relevant changes on Ebro delta can be described. In particular, the nautical charts of the Hydrographic Commission of 1878-1880 (Galvan et al., 1887) and 1886-1887 (Riudavets et al., 1890) allow the location of the shoreline and marsh domains of the Ebro Delta area about 130 year before present. Marsh domains location is important since these materials are prone to contain high quantities of organic matter which is highly compressible, boosting subsidence rates (especially if it is recent).

	Marshes in 1880
	Islands in the Ebro river in 1880

Approximate morphology of the Ebro Delta plain

The Ebro Delta is an active sedimentary system that throughout recent history has undergone very significant changes. Maps of the Ebro Delta produced before 1880 cannot be correctly projected on a present day coordinates system, as they lack of the necessary precision. This factor implies that this type of map is not valid to quantify the surface changes over the Ebro Delta plain. Nevertheless, this is valuable qualitative information which allows having a general idea of the delta formation processes, the sediment possible distribution and the intervals when the different delta domains have been emerged.

On the contrary, from the second half of the 19th century, more detailed and precise cartographic documentation is available, allowing its geographical referencing. As a consequence is possible to perform a more exhaustive analysis of the morphological evolution of the Ebro Delta plain shoreline and the sediment accumulated on the Ebro Delta front through the comparison of consecutive shorelines and bathymetries respectively. Each layer has a description for each extension of the Ebro Delta plain.

	Extension of the Ebro Delta plain in 3000 BP
	Extension of the Ebro Delta plain between VI and X centuries
	Extension of the Ebro Delta plain between X and XIII centuries
	Extension of the Ebro Delta plain in 1580
	Extension of the Ebro Delta plain in 1749
	Extension of the Ebro Delta plain in 1880

3.4 Sedimentary dynamics of the Ebro Delta front

This raster layer shows the sediment accumulated in a continuous way? on the Ebro Delta front, as an attribute you can access to the thickness in meters.

-2 m 0 m 24 m No data	Thickness (m)

3.5 Areas under the present day mean sea level

This vector layer show the areas which already are under the sea level

	Delta plain areas under the sea level

3.6 DInSAR Sentinel

Measures of the Ebro delta's movements were registered by using Satellite-based Differential Interferometry radar (DInSAR) technique. This is a remote sensing technique that uses a stack of satellite images to monitor the surface motion with millimetric precision. In the SENTINEL mission the gathered data covers the intervals from mid-2014 to 2017. Its associated attributes are code, UTM coordinates and the subsidence in mm/year units.

More than 15 12 - 15 9 - 12 6 - 9 3 - 6 Stability 3 - 6 6 - 9 9 - 12 12 - 15 More than 15	Subsidence velocity (mm/yr)

3.7 Dinsar ERS Envisat

This layer also shows measures registered by using Satellite-based Differential Interferometry radar (DInSAR) technique. For the ERS and ENVISAT missions the collected data covers the interval from 1992 to 2010. Its associated attributes are code, UTM coordinates and the subsidence in mm/year units.

More than 15 12 - 15 9 - 12 6 - 9 3 - 6 Stability 3 - 6 6 - 9 9 - 12 12 - 15 More than 15	Subsidence velocity (mm/yr)

3.8 Geophysical surveys and profiles locations

3.8.1 AMT

The magnetotelluric method (MT) uses natural electromagnetic fields (electrical storms, ionosferic currents) as a source to study subsoil structure. Simultaneous recording of the horizontal electric and magnetic field variations on earth surface allows to determine the electrical resistivity variation as a function of the frequency (depth). Its associated attributes are code and station type.

	AMT

3.8.2 Electrical resistivity tomography

The electrical resistivity tomography method (ERT) involves injecting electrical current into the earth and measuring the potential difference along a profile. In this way, apparent resistivity of soils and rock can be obtained as a function of depth and horizontal position. For this layer you can access to the information about profile number, name, length in meters, profile type and platform type.

	Electrical resistivity tomography

3.8.3 Geophysical log

Borehole geophysical logging techniques are based on measuring and recording continuously the physical properties of interest along a borehole using different probes. Analysis of the correlation between the different records (logs) allows characterizing lithological section and formation fluids. The attributes associated with this layer are code, start and end depth in meters and purpose.

	Geophysical log

3.8.4 Horizontal to vertical spectral ratio

The technique of the H / V spectral ratio is based on the seismic noise register with a single 3-component seismometer with which the fundamental frequency of the ground is obtained. The code, profile type and platform type are the attributes of this layer that you can access them if you click one of the points.

	Horizontal and vertical spectral ratio

3.8.5 Seismic noise array

The array technique registers the seismic noise with a constellation of sensors, the vertical profile of the speed of propagation of the shear waves is characterized. By combining this technique with H/V spectral ratio, the thickness of sediments

(Quaternary and / or Neogene) can be obtained. The attributes related to this layer are name of the sensor, its geometry, aperture, profile type and platform type.

o	Seismic noise array

3.8.6 Seismic reflection

Seismic reflection method is based on the propagation of seismic waves inside the earth. This method analyzes the reflected waves which are generated on or near the surface by a seismic source, travel down into the ground, reflect at a discontinuity (density and velocity contrast) and travel back up to the ground surface. Digital processing of seismic reflection data offers the opportunity to create cross-sectional images of the subsurface (seismic reflection section) showing the amplitude of the reflected wave at the correct horizontal and depth coordinate of the reflection point. The information associated to this layer is code, length in meters, profile type and platform type.

/	Seismic reflection

3.8.7 Seismic Surface waves (MASW) and seismic refraction (SRA)

Surface wave analysis allows to obtain the profile of wave propagation S with the depth. This technique is to measure the dispersive characteristics of the surface waves (phase velocity depending on the frequency) and invert them to estimate the properties of the soil (Vs).

While seismic refraction method is based on analyzing the travel times of waves refracted under the critical angle on subsoil interfaces (velocity contrasts). Seismic energy is radiated downwards into the ground from a seismic source on or near the ground surface (e.g. weight drop, explosives,etc.), critically refracted at the interface travelling along it and radiated back to the surface. Its associated attributes are its profile number, name, length in meters, profile type and platform type.

/	Seismic Surface waves (MASW) and seismic refraction (SRA)

3.9 Boreholes and samples

Boreholes, geological description and soil and borehole samples are compiled from the Institut Cartogràfic i Geològic de Catalunya (ICGC) and other databases as well as from scientific articles and PhDs. The soil and borehole samples compiled were primarily collected for diverse purposes and therefore the available parameters present some variations such as different grain size ranges and density considerations. For the borehole layer you can access to its code, elevation, length, top and bottom of its deposits, reference and source. While the sample layer has its code, characteristics, geological unit, unit number and source as attributes. Both layers include links to the borehole logs and sample profiles respectively as attached information when available.

	Borehole
	Sample (soils and boreholes)

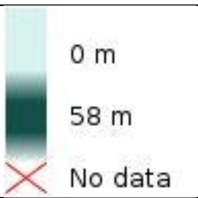
3.10 3D Model

The geological structure of the modern Ebro Delta is closely related to the evolution of the continental shelf over the last 20000 years (the last glacial maxima). Worldwide research on modern marine delta formation ages indicate that, regardless of latitudinal and climatic regime most of these depocenters are formed within a restricted period between 8000 and 6500 radiocarbon years before present (Stanley et al., 1994), when the sea rise rate began to decelerate (Siddall et al., 2003; Doyle et al., 2015). As a consequence, Ebro delta sedimentary body is composed by Holocene and Pleistocene transgressive units, grouped as the whole sedimentary body (QH20) and the Holocene sedimentary body (without Pleistocene units; QH).The main units can be synthetized in: QHlmpd, QHfd, QHprd, QPtf and QPtc.

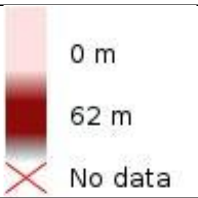
Each main unit is represented by several layers in the WMS, one represents the thickness of the deposit and you can access to thickness in meters, other the contour line map of the base of the deposit so you can get its elevation in meters and some of them has its limit with its description as attribute.

Unit	Description
QPtc	Upper Pleistocene transgressive coarse grained, sandy, deposits
QPtf	Upper Pleistocene transgressive fine grained, muddy, deposits.
QHprd	Holocene prodelta deposits
QHfd	Holocene delta front deposits
QHl	Holocene lagoonal (bay),mash, river overbank and alluvial plain deposits

QH deposits

	Thickness of the QH deposits (m)
	Contour line map of the base of QH deposits (m)

QH20 deposits

	Thickness of the QH20 deposits (m)
	Contour line map of the base of QH20 deposits (m)

QHlmpd deposits

0 m 25 m No data	Thickness of the QHlmpd deposits (m)
	Contour line map of the base of QHlmpd deposits (m)
	Limit of the QHlmpd deposits

QHfd deposits

0 m 17 m No data	Thickness of the QHfd deposits (m)
	Contour line map of the base of QHfd deposits (m)
	Limit of the QHfd deposits

QHprd deposits

0 m 50 m No data	Thickness of the QHprd deposits (m)
	Contour line map of the base of QHprd deposits (m)
	Limit of the QHprd deposits

QPtf deposits

0 m 18 m No data	Thickness of the QPtf deposits (m)
	Contour line map of the base of QPtf deposits (m)
	Limit of the QPtf deposits

QPtc deposits

0 m 22 m No data	Thickness of the QPtc deposits (m)
	Contour line map of the base of QPtc deposits (m)
	Limit of the QPtc deposits

3.11 Units distribution depth sections

Several layers are created to represent the geological units in sections. For each layer there are layer name and description as an attribute.

Distribution of the Holocene and Upper Pleistocene units at -5m elevation

	S5 QHlmpd
	S5 QHfd
	Substratum

Distribution of the Holocene and Upper Pleistocene units at -15m elevation

	QHfd
	QPtf
	Substratum

Distribution of the Holocene and Upper Pleistocene units at -25m elevation

	S25 QHprd
	S25 QPtf
	S25 QPtc
	Substratum

Distribution of the Holocene and Upper Pleistocene units at -35m elevation

	QHprd
	QPtf
	QPtc
	Substratum

Distribution of the Holocene and Upper Pleistocene units at -45m elevation

	QHprd
	QPtf
	QPtc
	Substratum

3.12 Map of the modern sedimentary environments of the Ebro Delta

The sedimentary units of the delta define and/or contain different sedimentary environments the environment limits are not clear, generally being a transicional boundaries.

However, the deposits associated with each of these environments generally have specific lithological, physical and/or chemical characteristics that make them likely to be differentiated if enough quality information is available. For each environment its geological unit, age and description are defined as an attribute. The different sedimentary environments determined on the Ebro Delta area are defined as:

	Mesozoic basement
	Neogene-Quaternary deposits
	Upper Pleistocene transgressive deposits.
	Holocene prodelta deposits
	Holocene delta front deposits
	Holocene lagoonal (bay) deposits
	Holocene marsh deposits
	Holocene overbank and alluvial channel deposits
	Holocene overbank deposits of the Ebro river valley

3.13 Subsidence susceptibility over Ebro Delta plain

Based on the geological and geotechnical characterization of the Holocene deposits, the study of the recent dynamics of the Ebro margin and the analysis of the DInSAR measures a subsidence susceptibility map of the Ebro Delta plain was produced.

This map contains quantitative information which indicate the averaged and a range of the expected subsidence susceptibility, and qualitative information which indicates domains where a higher subsidence rate can be expected (highly compressible units, organic matter-rich areas and sediments near the shoreline deposited beyond the 1923 shoreline, within the coastal enveloping area).

Delta Subsidence Susceptibility (mm/year)

> 1.5	(> 2.2)	Subsidence velocity (mm/yr)
1.25 - 1.5	(0.7-2.2)	
1 - 1.25	(0.6-2.0)	
0.75 - 1	(0.4-1.6)	
<= 0.75	(<=0.4)	

Maximum subsidence susceptibility (mm/year)

> 2.25	Subsidence velocity (mm/yr)
2 - 2.25	
1.75 - 2	
1.5 - 1.75	
1.25 - 1.5	
1 - 1.25	
<= 1	

Minimum subsidence susceptibility (mm/year)

> 1	Subsidence velocity (mm/yr)
0.75 - 1	
0.5 - 0.75	
0.25 - 0.5	
<= 0.25	

Highly compressible units

	QHmpd unit thickness >10m
	QHprd unit thickness > 10m

Organic matter-rich areas

	Organic matter–rich superficial soils
	QHm unit deposits

Coastal enveloping area

Define the maximum area combining the available shorelines since 1923.

	Shoreline progradation-retrogradation since 1923

4 LIFE EBRO Viewer

In order to make the information accessible without specific GIS software, the GEOINDEX LIFE EBRO viewer was created (figure 1). In this viewer the different layers contained on the WMS Service are defined and available for consultation online at:

http://www.icgc.cat/en/Public-Administration-and-Enterprises/Tools/Geoindex-viewers/Geoindex-Life-Project-EBRO

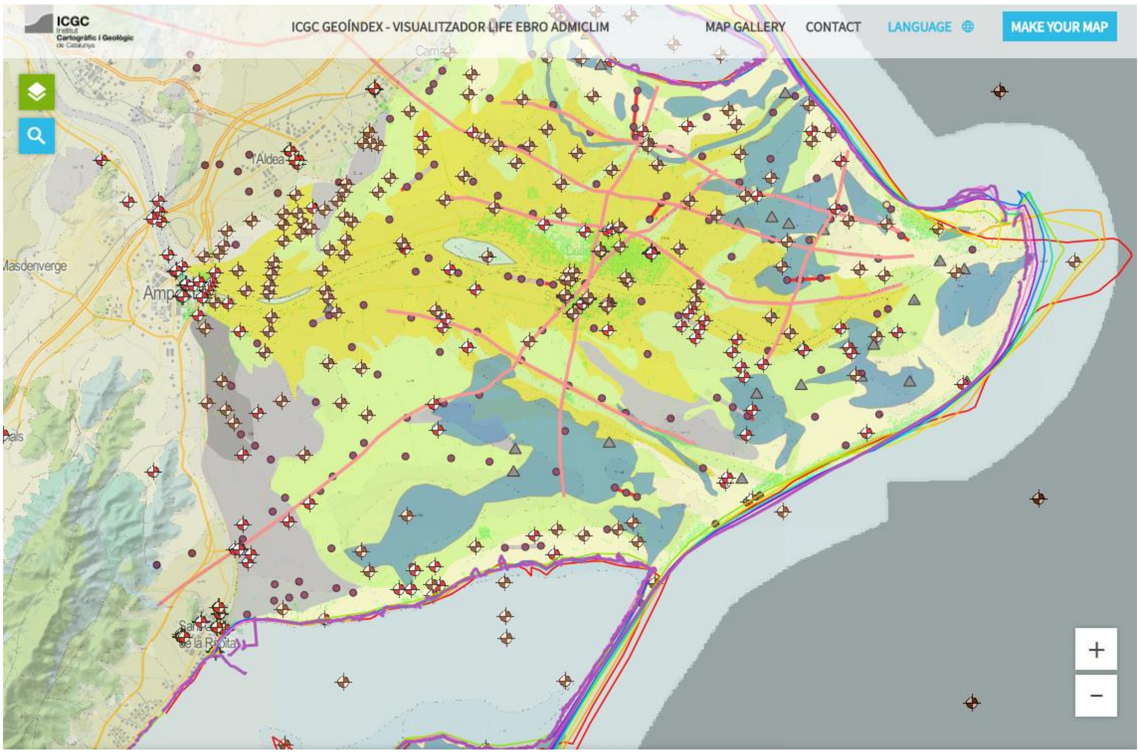


Figure 1. GEOINDEX LIFE EBRO viewer.