FACT SHEET: Ebro River Basin

The Ebro is the longest river (987 km) in Spain; it originates at Fontibre, flows through the gorges of Burgos Province, the limestones of central Ebro valley, and discharges in the Ebro delta on the Mediterranean Sea. The drainage area of the basin is 85,611 km². The Ebro Delta is one of the largest wetland areas (320 km²) in the region. Mean annual rainfall varies from 320 mm/y in the semi-arid central Ebro valley to more than 2000 mm/y in the Pyrenees and Cantabrian mountains. The population is more than 3.2 million inhabitants. Table 1 presents the main characteristics of the basin.

Figure 1. Ebro River drainage basin

Table 1. Ebro River Basin characteristics

Ebro
COUNTRIES: SPAIN, FRANCE
Pedo-climate: Sothern region; Mediterranean South, Mediterranean north, Mediterranean mountains, Lusitanian and Alpine south zones
Drainage Area 85,611 km^2
Maximum altitude: 3308 m
Annual average rainfall 475 mm/y
Main land uses: Agriculture 45.2%; Forest 53%, and Urban 1.3%
Population in 2015: 3,204,928
River length 987 km
Strahler Order – 8
Discharge at outlet 332 m^3/s
Outlet coordinates: 40° 43' 12" N, 0° 51' 47" E

Agricultural, urban, and industrial activities exert severe pressure on the aquatic habitats. About 45% of the Ebro basin is used for agriculture, 15% of which is irrigated. Agriculture is the main sector for water abstraction. Water demand for agriculture, livestock and aquaculture amount to 7,310 million m^3/y, compared to 506 million m3/y for domestic use, and to 250 million m^3/y for industry. Soil salinization caused by irrigation and agricultural runoff is a major problem for agricultural production.

Agriculture and water in the Ebro Basin

Intensive agriculture exerts severe pressure on freshwater resources of the Ebro River Basin, especially in terms of nutrient and pesticides fluxes from agricultural fields. Concentration and flows of nitrogen compounds in freshwaters associated with agriculture have increased during the last decades in the Ebro (Causapé et al., 2006). Nitrogen pollution pathways from croplands to streams and aquifers can be classified in three groups: 1) winter and spring flows from upland rainfed cereal cropping systems (Lassaletta et al., 2009; 2010; 2012), 2) percolation flows directly to aquifers from irrigated areas, and 3) irrigation return flows (Causapé and Aragüés 2004; Causapé et al., 2004; 2006; Valenzuela, 2009).

In the Ebro river basin, a combination of intense irrigation and excessive and inefficient fertilization, particularly in maize, is the first reason for N leaching (Cavero et al., 2012; Isidoro et al., 2006; Jego et al., 2008) and P pollution to waters (Dechmi et al., 2013). The critical periods of pollution occur at sowing in April and during summer. Fertilizing before irrigating and previously to corn sowing considerably increase the risk (Isidoro et al., 2006). In some places of the Ebro basin, P is exported as dissolved P in subsurface flows instead of superficial runoff (Skhiri and Dechmi, 2012) and is directly available for algal growth.

Flood irrigation is the most impacting irrigation technique (Garcia-Garizabal et al., 2012a; 2012b). Nitrate contamination and its relationship to irrigation management were assessed in the Bardenas Canal Irrigation District (Garcia-Garizabal et al. 2012a; 2012b). All nitrogen inputs and exports in 2005-2008 were measured to assess annual fluxes. The area has a free aquifer with saturated thicknesses up to 4 m with a maximum depth of 5.5 m. Fertilization rates were very high (121-162 kg N/ha/y). Export from the ditch (which represented groundwater base flow) ranged from 56 to 67 kg N/ha/y (41-46% of the fertilization rate), with mean annual nitrate concentration of 138-244 mg NO_3^-/L. Reduction of fertilization rates combined with improved irrigation efficiency could decrease nitrate exports importantly.

The transition from rainfed to irrigation can increase nitrogen pollution 3-fold (Merchan et al., 2014; 2015). Merchan et al. (2014) used hydrochemical and isotopic data to determine sources and processes affecting nitrate pollution and sulfate concentrations in groundwater (salinization) in the small irrigated Lerna basin, in the middle Ebro valley. The basin receives irrigation water from the Bardenas channel, and collects water from highly fertilized fields of maize, winter cereal, sunflower and vegetables. Synthetic nitrogen fertilization in the basin is a mixture of nitrate and ammonia compounds as well as urea. Water samples were taken in July 2011 and January 2012. Measured average concentration was 29 mg NO_3^- N/L (range: 18-39 mg/L) in groundwater, 37 mg NO_3^- N /L (29-52 mg/L) in springs, and 15 mg NO_3^- N /L (12-19 mg/L) in gullies. Over 93% of the nitrogen found in groundwater was in the form of nitrate, whose primary source was identified in the mineral fertilizers. The data also suggest that ammonia/urea fertilizers undergo volatilization as well as low *in situ* nitrification. Sulfate concentrations are affected by local soil and gypsum deposits.

Nitrate leaching from agricultural fields to groundwater in the Flumen catchment were assessed using SWAT model by Sorando et al. (2019). The Flumen catchment is mostly flat in its central and southern sections, and used for irrigated annual crops (maize, alfalfa, barley and rice). Other parts of the catchment are used for rainfed barley and wheat. Two canals bring irrigation water from the Pyrenees mountains to the catchment. The amount of nitrate leaching to the aquifer in the irrigated region was assessed at 100-250 kg N/ha/y. Conversely, lateral flow of nitrate to the drainage system was much larger, assessed at 1400-2000 kg N/ha/y. In this case thus, due to the drainage system, the surface waters are more impacted than groundwater.

Historical data and two sampling surveys (2002-2003) in the alluvial aquifer and in the Ebro River section between Tudela and Zaragoza were used to assess nutrient sources and dynamics as well as the impacts to surface and groundwaters (Torrecilla et al., 2005). The alluvial terraces of the area support traditional irrigation agriculture fed by the Imperial de Aragon canal. 40 wells and springs were sampled for N species, COD-UV (for the quantification of the impacts of manure application) and dissolved inorganic phosphorous. Mean nitrate concentrations were 57 mg NO_3^-/L in the NW half of the study area and 38 mg NO_3^-/L in the SE half. The difference between the areas was attributed to livestock density and extent of cultivated areas in the two sections.

Based on groundwater data, the annual nitrate load from non-point sources to the river was estimated at about 360 kg NO_3/d per km of river. Drainage canal data indicated that summer nitrate load was about 660 kg/d/km, phosphate-P load 0.5 kg/day/km, and the COD-UV load 204 kg/day/km, testifying the significant impacts of agriculture on surface and ground waters of the region.

Zufiaurre et al. (2020) focused on impacts on nitrates in the western side of Hoya de Huesca. 113 groundwater and 31 surface water samples were collected between 2014 and 2017 for water quality parameters. The results showed a clear difference in nitrate concentrations between the Pre-Pyrenees (karstic springs) and the Piedmont aquifers. Springs of the Pre-Pyrenees aquifers had nitrate concentrations lower than 5 mg NO_3^-/L, while aquifers of the piedmont area had values up to 200 mg NO_3^-/L. High nitrate concentrations were related to nitrogen fertilization of winter crops. 21 groundwater wells were sampled on a monthly basis between 2016 to 2017 to evaluate the nitrate variability over the year. The nitrate concentrations ranged from few mg NO_3^-/L to over 300 mg NO_3^-/L. The temporal evolution of nitrate was very stable in the wells with low concentration, and quite variable for the wells with over 100 mg NO_3^-/L. The authors concluded that nitrate contamination is persistent in the region, and suggest better measures are implemented to limit aquifer contamination.

While optimal fertilization (alone or in combination with improved irrigation) can be applied at the field/farm scale, solutions to reduce agricultural nutrient surplus can be planned at the basin-scale too (Causapé et al., 2006). A reduction of the share of maize cultivation has been recommended in some areas of the Ebro River Basin (Barros et al., 2012). The good use of the available organic resources is paramount to increase nitrogen use efficiency at the territorial scale, particularity in areas with high animal density where fertilization much above the optimum is common. For example, application rates of pig slurries higher than 30-40 t/ha/y are not sustainable (Yague and Quilez, 2010; 2015).

Arauzo et al. (2011) studied the distribution patterns of nitrogen in the aquifers of the alluvial aquifers of the Oja-Tiron and Zamaca rivers and their contribution to nitrogen export to the Ebro River. The aquifers are designated as Nitrate Vulnerable Zones (NVZ). The total area of the two watersheds is 1,349 km^2 and the land use is 57% agriculture, 31% forest, and 12% urban/other uses. At the time of the study, the agricultural land was predominantly irrigated; the main crops were sugar beet, potatoes, peas, green beans, cereals and vineyards. The livestock density was 6.7 in the Oja-Tiron and 4.5 Livestock Units/km^2 in the Zamaca watershed. Domestic emissions were low as a wastewater treatment plant is present in the area. Sampling campaigns were carried out biannually from April 2005 to April 2009. Nitrate was the predominant N species in groundwater (88% for the Oja aquifer and 93% for the Tiron). From the 30 stations sampled in the Oja aquifer, 19 had concentrations exceeding the standard drinking water threshold of 50 mg NO_3^-/L. The mean concentrations of nitrate in the Tiron aquifer ranged from 27 to 150 mg

NO_3^-/L. Overall, 66% of the sampling points exceeded the 50 mg NO_3^-/L threshold. The average export of nitrogen from the two catchments to Ebro was 2.4 kt N/y.

Arauzo (2017) revised the method to delineate NVZs based on catchment vulnerability. Nitrate concentration was measured at 872 sampling points in 46 main aquifers of the upper Ebro basin in five hydrological years (2005-2010). The nitrate concentration ranged from low to 382 mg NO_3^-/L. In 44 zones over 17 aquifers nitrate exceeded the 50 mg NO_3^-/L threshold; whereas 5 aquifers were at risk (nitrate levels between 25 and 50 mg NO_3^-/L). Alluvial aquifers were the most vulnerable (90% affected and 10% at risk). The study found that at least 1,728 km^2 should be designated NVZ, an area much larger than the 328 km^2 currently designated.

The impact of agriculture to groundwater of Ebro river basin was assessed by Lassaletta et al. (2012) with regional spatialized N budgets. The results indicate that although the Ebro receives a high amount of N input (5.1 t N/km^2/y, 50% of which is from agriculture), only 8% is exported to the Mediterranean Sea. On average, 91% of the agricultural nitrogen surplus reacts or is retained within the basin, thus likely exposing aquifers to contamination risk, or volatilize in the atmosphere. The study highlighted also the difficulty of improving groundwater quality due to slow response of the system and the issue of chronic accumulation of N surplus.

The impact of the agricultural pesticides on groundwater was the focus of Hildebrandt et al. works (2007; 2008). The first study assessed 30 priority pesticides and their derived products in groundwater and soil samples collected from agricultural fields in the upper and middle parts of the Ebro Basin. In groundwater the following pesticides were detected: Tributylphosphate (0.05-0.73 µg/L – pesticide additive), atrazine (0.01. – 0.17 µg/L), desethyl atrazine (bdl – 0.57 µg/L), and simazine (bdl to 0.08 µg/L). DEA/atrazine (2.32 – 5.84 µg/kg) and nonylphenol (bdl to 33.97 µg/kg) were detected in soils. Hildebrandt et al. (2008) assessed the impact of eight pesticides on surface and groundwater from vineyards of the Ebro, Duero and Mino river basins. The highest concentrations of pesticides were atrazine (0.01 – 1.42 µg/L), DEA (0.01 – 1.25 µg/L), Simazine (0.01 – 0.54 µg/L) and DES (0.01 – 0.79 µg/L). In general, concentrations in groundwater were higher than in surface water.

Surface water, groundwater and sediment/soil samples were collected along the Ebro River to determine organic pollution patterns (Terrado et al., 2010). Six sampling campaigns were conducted in 2004-2006 and 92 groundwater samples were collected and analyzed for 7 variables. The agricultural contamination was attributed mainly to triazines (atrazine, desethylatrazine, simazine and terbuthylazine). The concentrations in groundwater varied up to 6 µg/L (total score) with very stable patterns between the sampling sessions. Concentrations in groundwater were higher than in surface water. The results show a very clear pesticide contamination from agriculture all along the Ebro River aquifers.

Impact on coastal areas

Because P is assumed to be the limiting nutrient in freshwaters, and N the limiting one in marine systems (Elser et al., 2007), the decrease in P exports due to improvements of wastewater treatment plants is consistent with the observation of a strong reduction of river eutrophication (Torrecilla et al., 2005). Conversely, despite nutrients reduction, the Alfacs Bay still present episodic eutrophication crisis (Busch et al., 2016; Quijano-Scheggia et al., 2008, Fernández-Tejedor et al., 2009). Eutrophication takes various forms with development of harmful algal blooms (HAB), with accumulation of mucilaginous algae or dinoflagellates, Cyanobacteria, but mostly Pseudo-Nitzschia in this area, possibly producing toxic substances and/or leading to fishing prohibition.

Eutrophication potential is linked to the excess of nutrients delivery over that of silica (an element that favors diatoms) to a coastal bay system. This excess can be quantified with the indicator for coastal eutrophication potential ICEP (Billen and Garnier, 2007, based on the nutrient ratios by Redfield et al., 1963 and Conley et al., 1989). An ICEP value close to zero indicates equilibrium between nitrogen or phosphorus and silica, whereas positive or negative values mean an excess or deficit with respect to silica. In the Ebro coastal area, the ICEP-N value is currently estimated at 2.99 and ICEP-P at 1.30 kg C/km^2/day. Thus, while a relative balance has been reached between phosphorus and silica, ICEP-N is still positive and potentially conducing to eutrophication.

The studies above highlight the extensive impact of agriculture to freshwaters and coastal areas of the Ebro River Basin. Excessive fertilization rates generate nutrient surplus that is either leached to groundwater or collected in drainage canals and delivered to surface waters, posing serious threats of eutrophication. Soil and aquifers contamination of pesticides is documented by Hildebrandt et al. (2007; 2008) and Terrado et al. (2010). Improving groundwater quality will take much time due to slow response of the system and chronic accumulation of surpluses.

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