

Analysis of the major floods in the Ebro River basin (Iberian Peninsula) since 1600 AD

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The Ebro River basin is located in NE Iberian Peninsula and has an area of 85,001 km². It is divided in four sub-basins: Upper Ebro, Cinca, Segre, and Lower Ebro (Figure 1 and Table 1).

In spite of being only 27% of the basin area (Table 1), we suspected the Cinca and the Segre rivers of being the main contributors to the great floods of the Ebro at Tortosa, near the basin's outlet. This issue was addressed by López-Bustos (1972) and Davy (1979) with 20th century data.

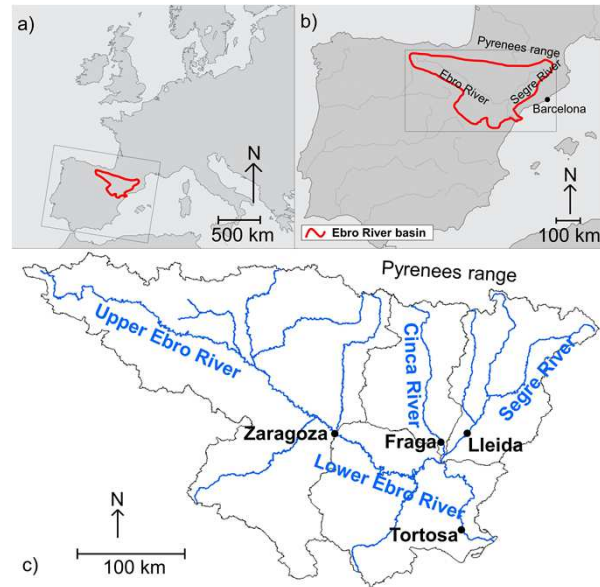


Figure 1. Location of the Ebro River basin within Europe (a) and the Iberian Peninsula (b), and map of the basin with its four sub-basins (c). Source: Own elaboration from a map Copyright © 2009 National Geographic Society, Washington, D.C.

Table 1. Basic features of the four sub-basins of the Ebro River basin. Source: Ebro Basin Authority (CH Ebro)

Sub-basin	Site	Area		Distance to Tortosa (km)	Mean flow	
		Area (km ²)	Percentage of total Ebro area at Tortosa		Mean flow (m ³ s ⁻¹)	Percentage of mean flow at Tortosa
Upper Ebro	Zaragoza	40,434	48	342	231	54
Cinca	Fraga	9,612	11	133	78	18
	Outlet	9,699	12	118	NA	---
Segre	Lleida	11,369	13	153	80	19
	Outlet	12,880	15	112	NA	---
Lower Ebro	Tortosa	21,217	25	---	428	100
	Outlet	21,988	---	---	NA	---
Total Ebro	Tortosa	84,230	100	---	428	100
	Outlet	85,001	---	---	NA	---

NA = not available

Our objective was to quantify the contribution of each of the three main sub-basins (Upper Ebro, Cinca, and Segre) to the greatest floods of the lower Ebro occurred in Tortosa in the last 400 years.

To do this, we compared the peak flows of 16 historical floods in the four sub-basins: Zaragoza, Fraga, Lleida and Tortosa (Table 2 and Figures 2 and 3).

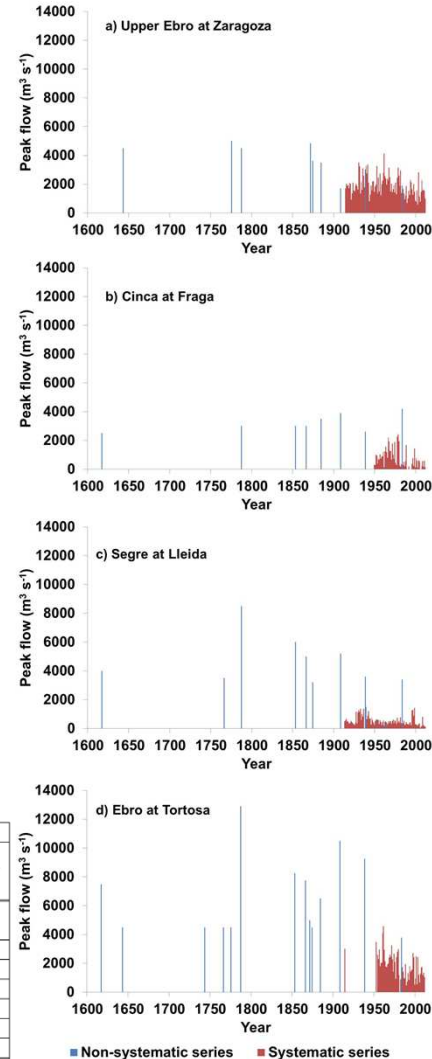


Figure 2. Non-systematic and systematic series of peak flows (Qci) at Zaragoza (a), Fraga (b), Lleida (c) and Tortosa (d). Source: Own elaboration from diverse sources (see Table 2)

The peak flows data were either estimated, either calculated with the HEC-RAS model from flood marks (Balasch et al. 2007; Sánchez 2007; Monserrate 2013), either calculated by the Ebro Basin Authority (CH Ebro).

As suspected, the Cinca-Segre system is the main generator of great floods (Figure 4). It is worth noting the different season of the floods depending on which sub-basin is the main contributor.

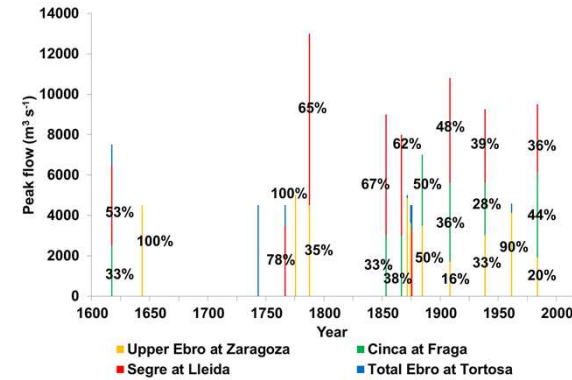


Figure 3. Approximate contribution of each sub-basin to the 16 analysed floods (some of the percentages do not appear due to lack of space; for full information, refer to Table 2). Source: Own elaboration from data in Table 2

References

- Balasch JC, Remacha R, Eritja X, Sánchez A (2007). 1907. La riuada del Segre a Lleida. Pagès Editors, Lleida, 229 p.
Davy L (1979). L'Ebre, étude hydrologique. PhD thesis, University of Lille
López-Bustos, A (1972). Antecedentes para una historia de avenidas del río Ebro. Rev. de Obras Públicas, 3083, 191-204
Monserrate A (2013). Reconstrucción de las avenidas de finales de siglo XIX en Zaragoza. Master's degree thesis, University of Lleida, 79 p.
Sánchez A (2013). Modelización hidráulica y análisis de magnitud-frecuencia de avenidas históricas en el curso bajo del río Ebro. Master's degree thesis, University of Lleida, 41 p.

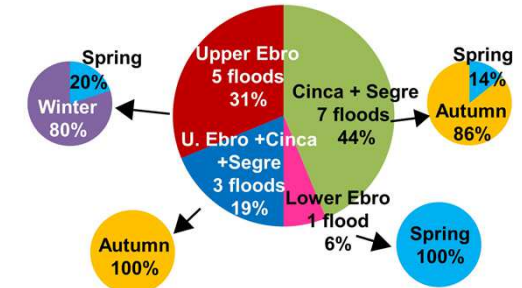


Figure 4. Most contributing sub-basins to each of the 16 analysed floods, and season of the floods. Source: Own elaboration

Table 2. Peak flows of the 16 analysed floods in the four sub-basins. Diverse sources (see footnotes)

Date of the peak flow at Tortosa			Peak flow (m ³ s ⁻¹)				Percentage over peak flow at Tortosa (%)				Most contributing sub-basin
Day	Month	Year	Upper Ebro at Zaragoza	Cinca at Fraga	Segre at Lleida	Ebro at Tortosa	Upper Ebro at Zaragoza	Cinca at Fraga	Segre at Lleida	Upper Ebro + Cinca + Segre	
8	11	1617	NF	2,500 ⁽¹⁾	4,000 ⁽²⁾	7,500 ⁽³⁾	NF	33	53	86	Cinca + Segre
18	2	1643	4,500 ⁽⁴⁾	NF	NF	< 4,500 ⁽¹⁾	100	NF	NF	100	Upper Ebro
18	6	1743	NF	NF	NF	< 4,500 ⁽¹⁾	NF	NF	NF	NF	Lower Ebro
19	12	1766	NF	NA	3,500 ⁽²⁾	< 4,500 ⁽¹⁾	NF	NA	78	≥78	Cinca + Segre
25	6	1775	5,000 ⁽²⁾	NF	NF	< 4,500 ⁽¹⁾	100	NF	NF	100	Upper Ebro
9	10	1787	4,500 ⁽²⁾	NA	8,500 ⁽²⁾	12,900 ⁽³⁾	35	NA	65	100	Upper Ebro + Segre
25	5	1853	NF	3,000 ⁽¹⁾	6,000 ⁽³⁾	8,250 ⁽³⁾	NF	33	67	100	Cinca + Segre
21	10	1866	NF	3,000 ⁽¹⁾	5,000 ⁽³⁾	7,750 ⁽³⁾	NF	38	62	100	Cinca + Segre
13	1	1871	4,844 ⁽³⁾	NF	NF	5,000 ⁽³⁾	97	NF	NF	97	Upper Ebro
---	1	1874	3,624 ⁽³⁾	NF	NF	< 4,500 ⁽¹⁾	81	NF	NF	81	Upper Ebro
23	9	1874	NF	NA	3,200 ⁽³⁾	< 4,500 ⁽¹⁾	NF	NA	71	≥71	Cinca + Segre
17	9	1884	3,500 ⁽³⁾	3,500 ⁽¹⁾	NF	6,500 ⁽³⁾	50	50	NF	100	Upper Ebro + Cinca
25	10	1907	1,700 ⁽⁴⁾	3,900 ⁽⁴⁾	5,200 ⁽³⁾	10,500 ⁽³⁾	16	36	48	100	Cinca + Segre
29	10	1937	3,020 ⁽⁴⁾	2,600 ⁽⁴⁾	3,600 ⁽⁴⁾	9,250 ⁽³⁾	33	28	39	100	Upper Ebro + Cinca + Ebro
2	1	1961	4,130 ⁽⁴⁾	NF	NF	4,580 ⁽⁴⁾	90	NF	NF	90	Upper Ebro
9	11	1982	1,910 ⁽⁴⁾	4,200 ⁽⁴⁾	3,400 ⁽⁴⁾	3,780 ⁽⁴⁾	20	44	36	100	Cinca + Segre

NA = not available

NF = no flood

⁽¹⁾ Estimated

⁽²⁾ Modelled with HEC-RAS from an approximate flood mark

⁽³⁾ Modelled with HEC-RAS from an exact flood mark

⁽⁴⁾ Calculated by the Ebro Basin Authority (CH Ebro)

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