**River sediment fluxes to the ocean**

**(Student Version)**

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1. **Introduction**

Rivers are the most important source for water and sediment from land to the ocean, and they form a broad plain at the coastal zone, comprising deltas and estuaries. The amount of sediment flux from river to the ocean is a critical factor that determines the evolution of these coastal morphological units.

For instance, the increase of sediment flux may speed up the progradation rate of coast line into the ocean; on the other hand, the decrease the sediment flux to the ocean, may cause a coastline to be eroded and to retreat.

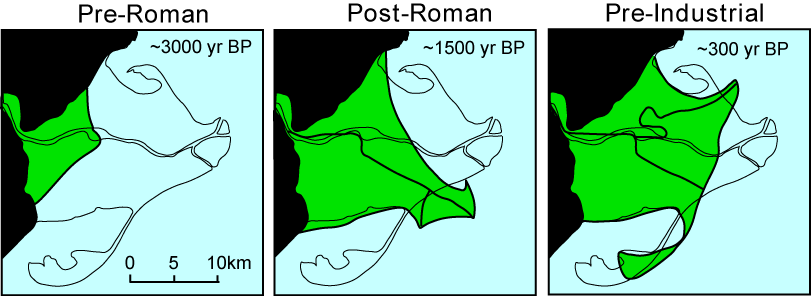


Figure 1. The evolution of Ebro Delta over the last 3000 years.

Figure 1 shows the evolution of Ebro Delta in Spain, which forms at the mouth of the Ebro River. The delta sediment is redistributed by wave action of the Mediterranean Sea. The Ebro Delta built out significantly, over more than 10 km, in the last 3000 years. Rapid progradation followed prehistoric and Roman deforestation, continuing into the Middle Ages. However, presently it is estimated that more than half of the Ebro delta will be lost within the next 50 years. Approximately 47% of its delta lowlands lie only 50 cm above sea level, and several cultivated areas in Ebro delta lie below sea level. Damming of the upper reaches of the Ebro River has caused sediment loss, and erosion of the delta front (of upto 15 meters a year) is now a serious problem. Global sea level is estimated to be rising at approximately 1.5 mm per year and the delta is currently sinking due to the weight of sediment by between 1 - 8 mm a year. (<http://geographyfieldwork.com/Ebro%20Delta%20Natural%20Park.htm>)

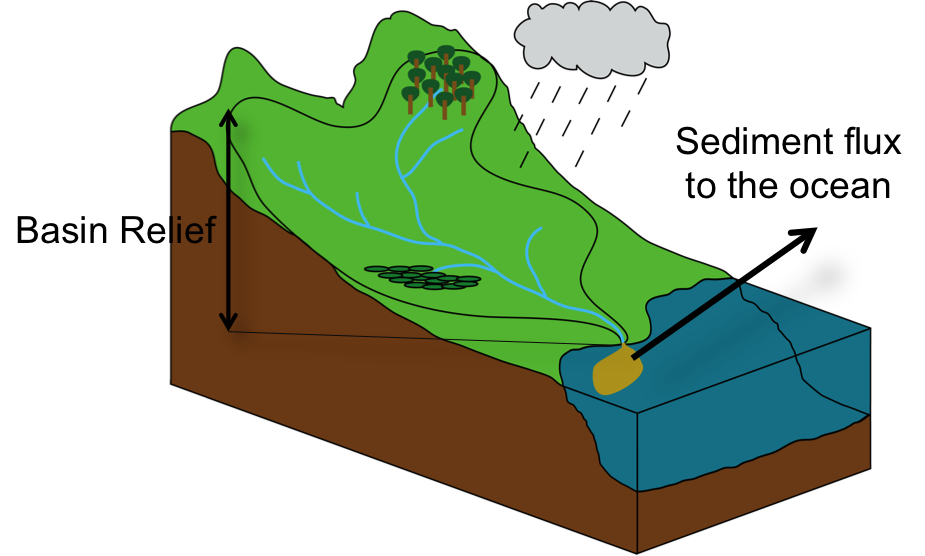
**2 Model Approach**

One model that can model sediment fluxes to the global ocean is HydroTrend. HydroTrend is a numerical model that creates synthetic river discharge and sediment load time series as a function of climate trends and basin morphology and has been used to study the sediment flux to marine basins. As a drainage basin simulator, the model provides time series of daily discharge hydraulics at a river mouth, including the sediment load properties. HydroTrend was designed to provide input to lake or shelf circulation and sedimentation, and study the impact of land-sea fluxes given climatic change scenarios.

HydroTrend simulates the major processes that occur in a river basin, including:

* Glacial processes with advances and retreats depending on the climate scenario,
* Snow accumulation in the winter and melt in the subsequent spring/summer,
* Rainfall with canopy or vegetation evaporation,
* Groundwater recharging and discharging,
* The impact of lakes and reservoirs.

The following cartoon shows the hydrologic process that Hydrotrend simulates, it uses climate changes (precipitation and temperature) as input parameters to calculate the river water discharge and sediment flux to the ocean at the river mouth, other factors, like the lithology, anthropogenic factors, glacier area, basin area and relief are all considered in the model equations. It is important to realize that HydroTrend is a 1D, point source model, which uses the averaged value for the whole basin, and that it is a generic model, which is not specific to a certain river basin.



More detailed information on HydroTrend can be found on this website: <http://csdms.colorado.edu/wiki/Model:HydroTrend>

Related literature:

*Kettner, A.J., and Syvitski, J.P.M., 2008. HydroTrend version 3.0: a Climate-Driven Hydrological Transport Model that Simulates Discharge and Sediment Load leaving a River System. Computers & Geosciences, Vol. 34, 1170-1183.*

*Syvitski, J.P.M. and Milliman, J.D., 2007, Geology, geography and humans battle for dominance over the delivery of sediment to the coastal ocean. J. Geology 115: 1-19.*

*Vorosmarty CJ, Meybeck M, Fekete B, Sharma K (1997) The po- tential impact of neo-Castorization on sediment transport by the global network of rivers. In: Human impact on erosion and sedimentation. Proceedings of the Rabat Symposium, IAHS Pub. No. 245:261–273*

**Practice:**

*Question for Students 1*

*The most important output parameters calculated with the Hydrotrend model are the water discharge, Q, and sediment flux at the river mouth, Qs. What do you think are the factors that will influence water and sediment output at a river mouth? How do you think these factors will influence the resulting sediment flux? (Hint: describe effects of two aspects: human activities and natural factors).*

*Question for Students 2*

*2A In the Excel file named RiverFluxtoOcean.xlsx, there are three separate worksheets. The worksheet called ‘Suspended load’ shows the equation used in Hydrotrend for the calculation of suspended sediment load. First read the equation and the example for Ebro delta, and then calculate the value of sediment flux for the given groups, while thinking about the following question: What happens to Qs if the mean annual temperature increases? And why?*

2B *What happens to Qs if the mean annual discharge increases? And why? What could cause this?*

*2C What happens to Qs if B increases? And what could lead to this?*

2D *What factor could cause B to decrease for the Ebro River?*

2E *Plot a graph of Qs as a function of step-wise temperature change. How much range would the temperature axis have? For example how much change in mean annual temperature occurred approximately between the last glacial maximum (the last ice age, approximately 21,000 yrs ago) and the present? (Hint: look in Weaver A.J., et al., 1998).*

*Question for Students 3*

*3A In the Spreadsheet RiverSedimentFluxtoOcean.xls, on the worksheet called ‘bedload’ , we show the equation used in Hydrotrend for the calculation of river bedload. How does bedload change with channel slope or water discharge? Think about one question: the construction of dam close to the river mouth will trap all the bedload from the basin, however, the modeled result does not reflect this trapped bedload, could you give the reason? (Hint: the discharge is not zero after dam construction).*

3B *Plot a graph of Qb versus river channel slope, S; what is the range of slopes in natural deltas (the so-called gradient of the delta plain) approximately? (Hint: you can look in Syvitski and Saito, 2007. Global and Planetary Change)*

*Question for Students 4*

*The HydroTrend model uses Brune and Brown equations to estimate the reduction of sediment load from damming, the equations are shown in sheet 2. Calculate the reduction of sediment load caused by different values of dam mean volume, and river discharge. What could you get from the Qs changes? (Reference: Brown, 1943; Brune, 1953)*

*Additional References:*

*Brown, C.B., 1943. Discussion of sedimentation in reservoirs, by J. Witzig. Proceedings of the American Society of Civil Engineers 69, 1493–1500.*

*Brune, G.M., 1953. Trap efficiency of reservoirs. Transactions American Geophysical Union 34, 407–418.*

*Syvitski, J.P.M., Saito, Y., 2007. Morphodynamics of deltas under the influence of humans. Global and Planetary Change 57, 261–282.*

*Weaver A.J., Fanning A.F., Eby M., Wiebe E.C.,1998. The climate of the last glacial maximum in a coupled ocean GCM/ Energy-moisture balance atmosphere model, Nature 394 : 847~853.*