European Sediment Research Network

Acronym: SedNet

EC contract No. EVK1-CT-2001-20002

Key action 1.4.1 Abatement of water pollution from contaminated land, landfills and sediments

A first attempt to approximate Europe's sediment budget

AUTHORS	**CHECKED & APPROVED BY**	**CO-ORDINATOR:**	
Philip N. Owens (National Soil Resources Institute, Cranfield University, UK) E-mail: philip.owens@bbsrc.ac.uk Ramon J. Batalla (University of Lleida, Catalonia, Spain) E-mail: RBatalla@macs.UdL.es	SedNet co-ordinator	Jos Brils TNO-MEP, The Netherlands Tel +31 223 638 805 Fax +31 223 630 687 E-mail: j.m.brils@mep.tno.nl	
DELIVERABLE OF	**DATE**		
SedNet Work Package 2 'Management at the basin scale'	30 November 2003		
-	-	FILE SedNet approximation of EU sediment budget.doc	No. of pages: 1

Content

1. Introduction

1.1. Background

Europe faces regulations like the Water Framework Directive, Thematic Strategy for Soil Protection, Habitats and Birds Directive, Marine Strategy etc. These regulations influence the best management practices in sediment management and *visa versa*. The sediment issue is fragmentary addressed and it is for very specific issues only covered by these EU policies and directives. In general, one of the most difficult barriers for implementation of sediment related scientific progress into EU policy making might be the lack of awareness on sediment issues. For instance, the EU WFD aims to develop sustainable river basin approaches in order to achieve and maintain the goal of 'good status' of all surface and ground waters by the year 2015. There is no direct focus on the management of sediments within the WFD. Sediments, however, are an essential and integral part of the aquatic ecosystem and, thus, of the river basin. From this perspective it is clear that the goal of the WFD can only be achieved if sediments are also addressed (Brils 2003).

One of the objectives of SedNet is to raise awareness on European sediment issues, for instance on the extend of the European sediment issue, being the scope of this paper.

SedNet is the acronym for the demand driven, European Sediment Research Network. The SedNet objective is to form on a European scale inter-disciplinary links and trans-disciplinary bridges between scientist, engineers, sediment managers and those responsible for developing and implementing sediment related policy. The SedNet activities are financially supported for three years by the EC under the FP5 EESD programme and within area 1.4.1 on "Abatement of water pollution from contaminated land, landfills and sediments" (Thematic Network project, EC contract No. EVK1-CT-2001-20002, starting date: 1 January 2002). The main deliverable of the SedNet project will be a publication with guidance on sustainable sediment management (SSM).

1.2. Objective

The objective of this paper is to enhance the awareness of the extend of the European sediment issue by providing a first approximation of Europe's sediment budget.

1.3. Status of this paper

This document presents very approximate estimates of the sediment budget (primarily for suspended sediment) for Europe. The budget is based on very general estimates of soil erosion, sediment yield, sediment storage on river channel and floodplain environments and in reservoirs, and estimates of the sediment discharge to oceans and seas.

These estimates are themselves based on typical values for select river catchments, which are then extrapolated to large geographical areas. The values presented represent order of magnitude approximations at this stage.

It is also important to note that, for simplicity, we have used a value of **6×10^6 km^2 to represent the surface area of the EU** (Member States, New Member States and Applicant Countries).

This first attempt to approximate Europe's sediment budget is regarded as a starting basis for an improved paper next year. Sediment quantity experts from the SedNet community are warmly invited to come with suggestions for that improvement.

Comments can be send directly by e-mail to the authors:

Dr. Philip N. Owens
National Soil Resources Institute, Cranfield University, UK
Leader of SedNet work package 2 'Sediment management at the basin scale'
E-mail: philip.owens@bbsrc.ac.uk

Dr. Ramon J. Batalla
University of Lleida, Catalonia, Spain
Core team member of SedNet Work Package 2 'Sediment management at the basin scale'
E-mail: RBatalla@macs.UdL.es

1.4. Structure of this paper

In the next sections of the paper the following is described:

Section 2: A preliminary answer to the sediment quantity questions:
- How much is being eroded from rocks and soils and delivered to rivers?
- How much is being delivered from rivers to the seas?
- How much is stored/extracted in between production and deposition areas?

Section 3: An overall, rough estimation of Europe's sediment budget

Section 4: A comparison with published estimates

Section 5: References

2. Sediment quantity questions and (preliminary) answers

2.1. How much is being eroded from rocks and soils and delivered to rivers?

Erosion rates (sediment production) range from 100 t km^{-2} $year^{-1}$ in humid environments, (northern Europe), to 500 t km^{-2} $year^{-1}$ in Mediterranean humid environments (mid-southern Europe), to 2500 t km^{-2} $year^{-1}$ in semiarid regions (southern Europe). From these figures we can estimate the total amount of sediment delivered from land to rivers as follows:

- 100 t km^{-2} $year^{-1}$ x 75% of Europe's area (6 x 10^6 km^2) = 450 x 10^6 t $year^{-1}$
- 500 t km^{-2} $year^{-1}$ x 20% of Europe's area (6 x 10^6 km^2) = 600 x 10^6 t $year^{-1}$
- 2500 t km^{-2} $year^{-1}$ x 5% of Europe's area (6 x·10^6 km^2) = 750 x 10^6 t $year^{-1}$

which gives a total of ca. **1800 x 10^6 t $year^{-1}$.** This result would typically not include bedload (i.e. coarse-grained sediment), which is likely to be between 10 and 20% of this value, although could reach up to 50% of the total in mountain areas.

2.2. How much is being delivered from rivers to the seas?

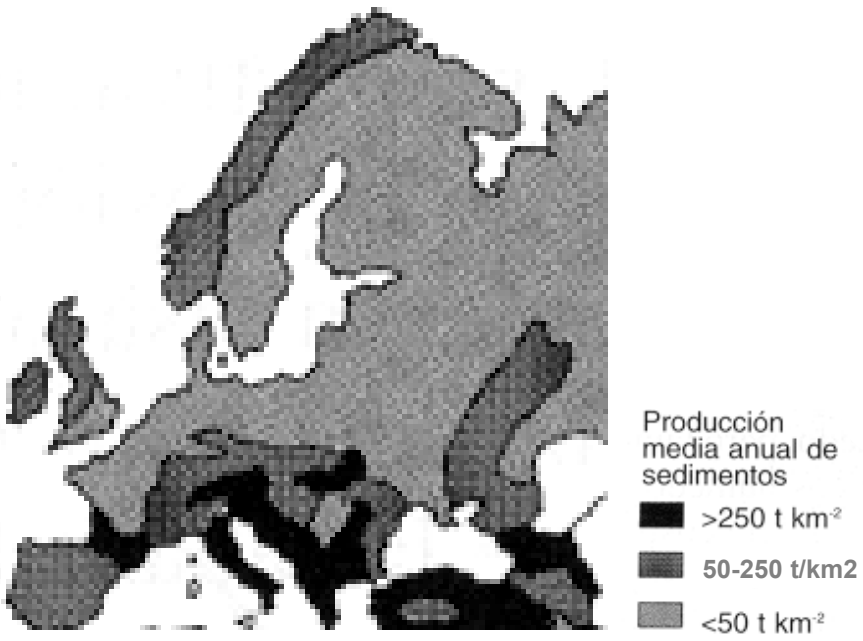

Figure 1. Sediment yield of rivers in Europe (bedload is not included) *(Walling and Webb, 1983)*

According to Walling and Webb (1983) (Figure 1), sediment yields range from <50 t km^{-2} $year^{-1}$ in humid low relief environments, to 150 t km^{-2} $year^{-1}$ in Mediterranean low-relief environments, to 500 t km^{-2} $year^{-1}$ in both humid and Mediterranean mountainous regions (e.g. Coastal Ranges in Spain and Italy, Pyrenees, Alps). From these figures we can estimate the total amount of sediment transported by rivers towards the lowermost land areas (deltas, harbours, estuaries, etc.) as follows:

- 40 t km^{-2} $year^{-1}$ x 60% of Europe's area (6 x 10^6 km^2) = 144 x 10^6 t $year^{-1}$
- 150 t km^{-2} $year^{-1}$ x 30% of Europe's area (6 x 10^6 km^2) = 270 x 10^6 t $year^{-1}$
- 500 t km^{-2} $year^{-1}$ x 10% of Europe's area (6 x 10^6 km^2) = 300 x 10^6 t $year^{-1}$

which gives a total of ca. **714 x 10^6 t $year^{-1}$**. This result does not include bedload, which could be 10% of the total sediment load (coarse and fine) reaching depositional zones in the lowlands.

2.3. How much is stored/extracted in between production and deposition areas?

a) In-channel sediment storage of fine-grained sediment ranges between 5% to 10% of the sediment delivered to rivers, which equates to 90 x 10^6 t $year^{-1}$ to 180 x 10^6 t $year^{-1}$. This value does not include the sedimentation of coarse-grained sediment (i.e. bedload).

b) Floodplain sedimentation of fine sediment may account for 10% to 50% (cf. Owens *et al.*, 1999) of the sediment delivered to rivers, which equates to between 180 and 900 x 10^6 t $year^{-1}$.

c) If it is assumed that within-channel sediment storage does not represent a net loss to the system at the annual timescale, and that floodplain storage does represent a net loss (Owens *et al.*, 1999), then the average estimate of floodplain storage is **540 x 10^6 t $year^{-1}$** (Figure 2).

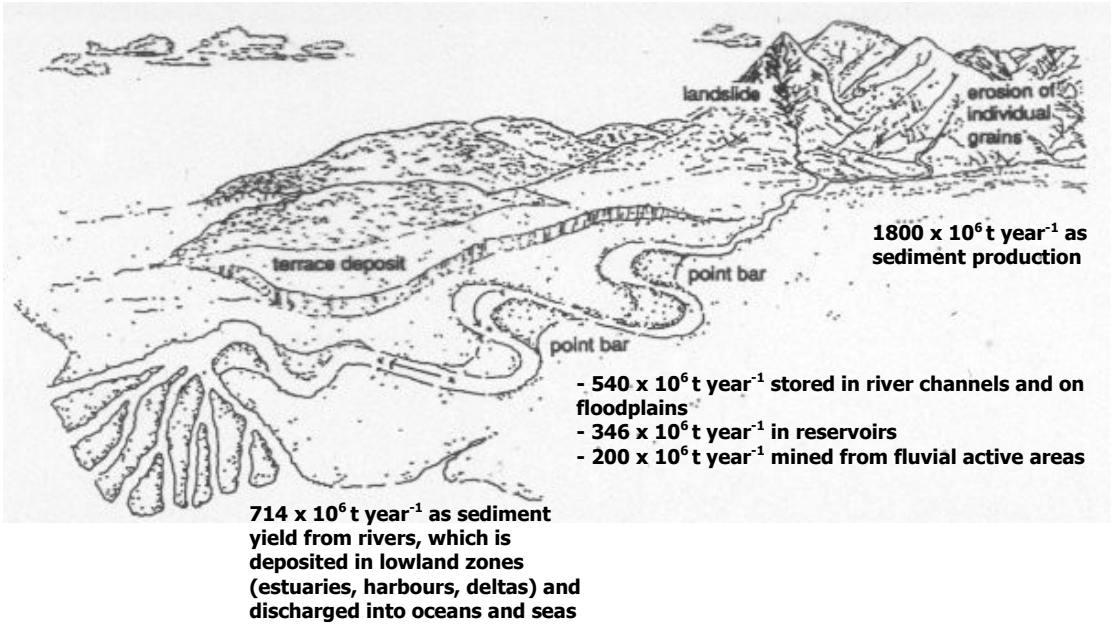

Figure 2. An approximate sediment budget for Europe *(Original bottom sketch from Kondolf, 1997)*

d) The average consumption of sediment (as aggregate for construction) in Europe can be estimated at around 2000 x 10^6 t $year^{-1}$ (ca. 7 t $person^{-1}$ $year^{-1}$), of which at least 1/3 is mined from rivers (bedload) and floodplains (both bedload and suspended sediment). This estimation would lead to a value of around 600 x 10^6 t $year^{-1}$, 1/3 of which can be replaced annually by rivers during floods (**200 x 10^6 t $year^{-1}$**) and 2/3 can be attributable to the mining of ancient river deposits (Figure 2).

e) The rest **346 x 10^6** t $year^{-1}$ are deposited in reservoirs/lakes (Figure 2). This value agrees with the low values of siltation in reservoirs (e.g. in Spain = 50 x 10^6 t $year^{-1}$) (Batalla, 2003).

3. Overall (rough) estimation of the sediment budget

How 100 units of sediment eroded in European catchments would be distributed downstream on an annual timescale?

⇒ **30 units** would be deposited on floodplains

⇒ **19 units** would be deposited in reservoirs

⇒ **11 units** would be extracted for aggregate

⇒ **40 units** would reach the lowermost deposition zones and the coastal zone.

Estimations indicate orders of magnitude of each of the main sediment-related processes in rivers of Europe, and so considerable caution should be used with these values. Uncertainty is high due to the lack of extensive, reliable and homogeneous data on sediment production, transport and deposition for all European river catchments.

SedNet research recommendation: Because of the limitations associated with the values presented above, there exists a need for a comprehensive Europe-wide assessment of sediment fluxes and transfers within European rivers, and the delivery of sediment to the coastal zone.

4. Comparison with published estimates

One of the most comprehensive estimates of the amount of sediment delivered world-wide to the oceans was by Milliman and Meade (1983), who used suspended sediment yield data for the major rivers of the world to estimate sediment delivery. For Europe (excluding Eurasian Arctic), they estimated sediment delivery for the major rivers draining eastwards (towards the Black Sea), westwards into the Atlantic, and southwards into the Mediterranean, as follows:

1. Eastwards (Danube and Dneper rivers) = 133 x 10^6 t $year^{-1}$
2. Southwards (Po, Rhone, Tiber and Ebro rivers) = 66 x 10^6 t $year^{-1}$
3. Westwards (Seine, Oder, Vistula, Rhine and Garonne rivers) = 31 x 10^6 t $year^{-1}$.

TOTAL = 230 x 10^6 t $year^{-1}$ (drainage area = 4.61 x 10^6 km)

It is uncertain, how this total value accounts for (or considers) potential floodplain storage, reservoir storage and sediment mining effects. It is also important to state that it is only based on selected rivers for parts of Europe.

Also, Lajczak and Jansson (1993) estimated that the delivery of sediment to the Baltic Sea was 4.5 x 10^6 t $year^{-1}$.

These values listed above compare to an estimate of the world-wide sediment delivery to oceans of between 15-20 x 10^9 t $year^{-1}$ (Milliman and Syvitski, 1992).

5. References

Batalla, R.J. (2003): Sediment deficit in rivers caused by dams and instream gravel mining. A review with examples from NE Spain. *Cuaternario y Geomorfología*, **17** (3-4), 79-91.

Brils, J.M. (2003): SedNet corner (European Sediment Research Network). *Journal of Soil & Sediments*, **3**(4). 267-268.

Kondolf, G.M. (1997). Hungry water: effects of dams and gravel mining on river channels. *Environmental Management*, **21**(4), 533-551.

Lajczak, A. and Jansson, M.B. (1993). Suspended sediment yield in the Baltic drainage basin. *Nordic Hydrology*, **24**, 31-52.

Milliman, J.D. and Meade, R.H. (1983). World-wide delivery of river sediment to the oceans. *Journal of Geology*, **91**, 1-21.

Milliman, J.D. and Syvitski, J.P.M. (1992). Geomorphic/tectonic control of sediment discharge to the oceans: the importance of small mountainous rivers. *Journal of Geology*, **100**, 525-544.

Owens, P.N., Walling, D.E. and Leeks, G.J.L. (1999). Deposition and storage of fine-grained sediment within the main channel system of the River Tweed, Scotland. *Earth Surface Processes and Landforms*, **24**, 1061-1076.

Walling, D.E. & Webb, B.W. (1983): Patterns of sediment yield. In: Gregory, K.J. (ed.): *Background to Paleohydrology*. John Wiley and Sons, Chichester, 69-100.