UNDERSTANDING THE FINE SEDIMENT BUDGETS OF RIVER BASINS

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1 THE CONTEXT

Traditionally, interest in the fine (suspended) sediment loads of rivers has focussed on documenting the magnitude of such loads and associated specific sediment yields and their variation in space and time. However, in many countries, such as the UK, the fine sediment load of a river was seen as being of limited significance and measurement programmes were limited or even absent. Growing recognition of the importance of fine sediment as a vector for the transfer of nutrients and contaminants through terrestrial and aquatic systems and its role in degrading aquatic ecosystems and habitats has, however, directed attention to the need to know more about fine sediment transport by rivers and to develop sediment management strategies. It has become clear that information on the sediment flux at the outlet of a catchment or river basin remains important, but that there is also a need to understand the internal functioning of the catchment in terms of sediment mobilisation, transfer and storage. Such understanding is encapsulated by the sediment budget, which integrates information on sediment sources and sediment mobilisation, sediment transfer and storage, and the resultant sediment output. The sediment budget must be seen as a key tool for understanding fine sediment fluxes and the likely impact of environmental change on such fluxes and for developing effective fine sediment management strategies (Walling and Collins, 2008; Gellis and Walling, 2011). The need to establish sediment budgets and investigate their functioning has highlighted the requirement for new approaches to studying catchment sediment fluxes and the value of tracing techniques (Walling, 2006). This contribution presents several examples of studies undertaken by the author and his co-workers aimed at developing an improved understanding of the fine sediment budgets of catchments and river basins.

2 SEDIMENT SOURCES

Information on sediment source must be seen as central to an understanding of catchment sediment budgets and the establishment of successful sediment management strategies. Sediment source exerts a key control on sediment properties and sediment-associated nutrient and contaminant fluxes and to be cost-effective sediment control measures must target the main sediment sources. Obtaining reliable information on sediment source is not easy and traditional monitoring techniques are of limited value. However, the successful development and application of sediment source fingerprinting techniques over the past 25 years now offers the potential to obtain such information and to quantify the relative contribution of both spatial sources and individual source types to the sediment load of a river (e.g. Walling, 2005). Figure 1 provides an example of such work undertaken in two sets of contrasting catchments in England and Wales, reported by Walling et al. (2008). Integration of the results of several such studies has provided a basis for assessing the relative importance of channel and surface sources within the UK more generally.

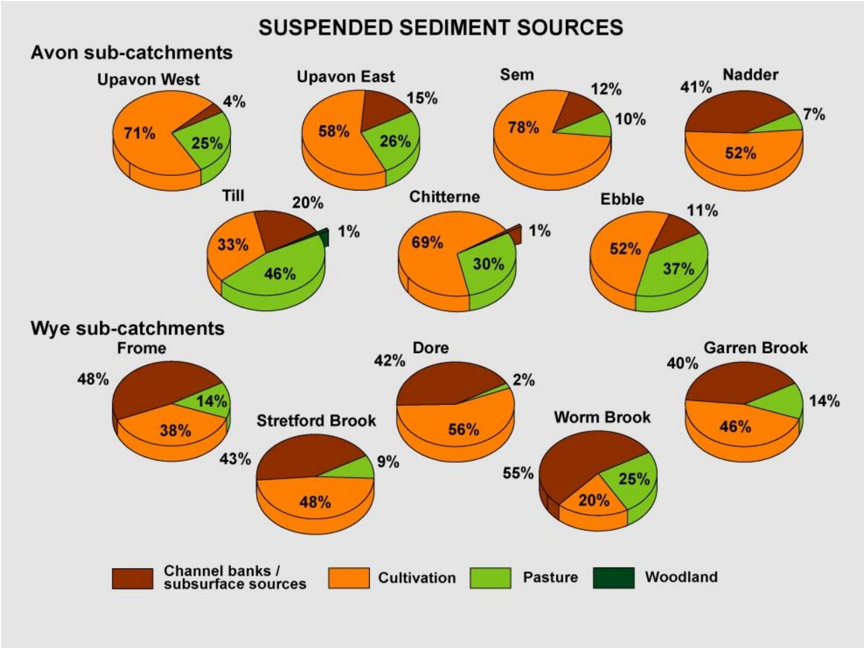

Figure 1 The relative contributions of different suspended sediment sources to the sediment output from two contrasting sets of catchments in England and Wales (based on Walling et al., 2008).

3 SEDIMENT MOBILISATION AND DELIVERY

In order to establish a sediment budget, information on sediment source must be integrated with information on sediment mobilisation rates from specific sources and the efficiency of sediment delivery from source to the channel network. Obtaining such information for surface sources presents a major challenge, but the use of fallout radionuclide tracers and particularly ^{137}Cs has been shown to possess considerable potential for elucidating these aspects of the sediment budget across a range of spatial scales. For example, Walling and Zhang (2010) report the use of ^{137}Cs measurements in a national reconnaissance survey to document the magnitude of both gross and net soil erosion rates on agricultural land within England and Wales (Figure 2). This information can be combined with equivalent data on landscape scale connectivity to establish the sediment input from surface sources to the channel network. Work reported by Porto et al. (2011), undertaken on small and intermediate sized catchments (0.015 – 31.6 km2) in Southern Italy, has similarly shown how ^{137}Cs and excess ^{210}Pb measurements can be used to establish the components of their sediment budgets related to sediment mobilisation and delivery from the catchment slopes (Figure 3).

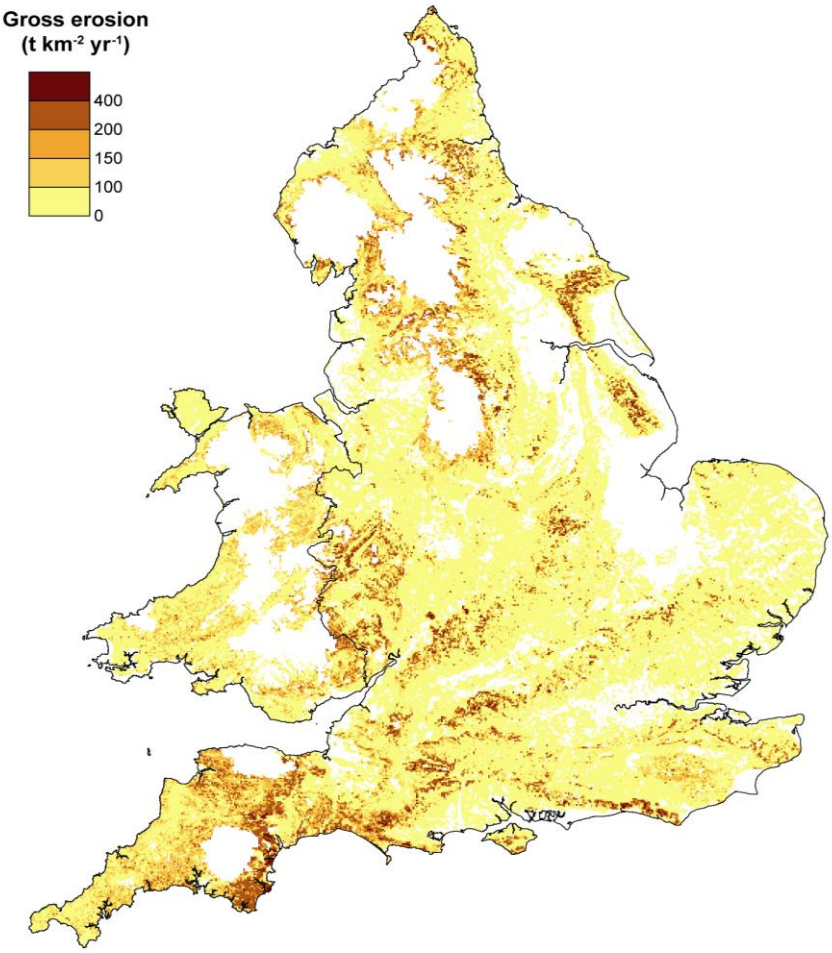

Figure 2 Gross rates of soil loss from agricultural land in England and Wales

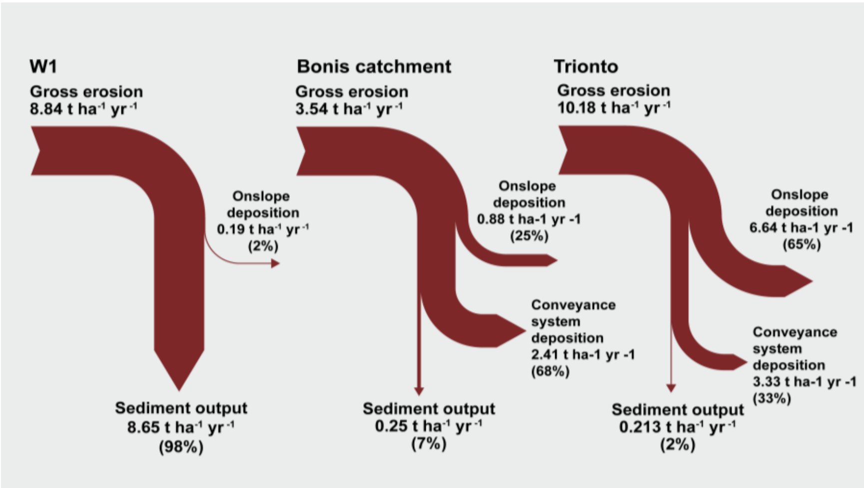

Figure 3 The sediment budgets of three small and intermediate-sized catchments in Southern Italy (based on Porto et al. 2011)

4 SEDIMENT STORAGE

It is important to recognise that much of the sediment mobilised from the surface of a catchment is likely to be deposited or stored before reaching the channel network. As indicated above, studies involving the use of ^{137}Cs and other fallout radionuclides can shed important light on the magnitude of such storage on the slopes of a catchment. Equally, sediment moving through the channel system may be deposited before reaching the catchment outlet. Storage of fine sediment within the channel system is commonly transitory, but overbank sedimentation on river floodplains can represent an important long-term conveyance loss for fine sediment moving through a river system. Fallout radionuclides again provide a valuable means of assessing the magnitude of such losses. Studies undertaken on the floodplains of several UK rivers have demonstrated that conveyance losses can account for as much as 40-50% of the sediment delivered to the channel network.

5 COMPLETING THE BUDGET

Information on the various components of a catchment budget will need to be integrated before the final budget can be constructed. Figure 4 based on work reported by Walling et al. (2006) shows the final sediment budgets for two medium-sized catchments of the Rivers Pang (166 km^2) and Lambourn (234 km^2) located on the Chalk of Southern England. In this case, the budgets emphasise the important of storage within these two groundwater dominated catchments. Their sediment outputs represent only ca. 1% of the sediment mobilised with the catchment.

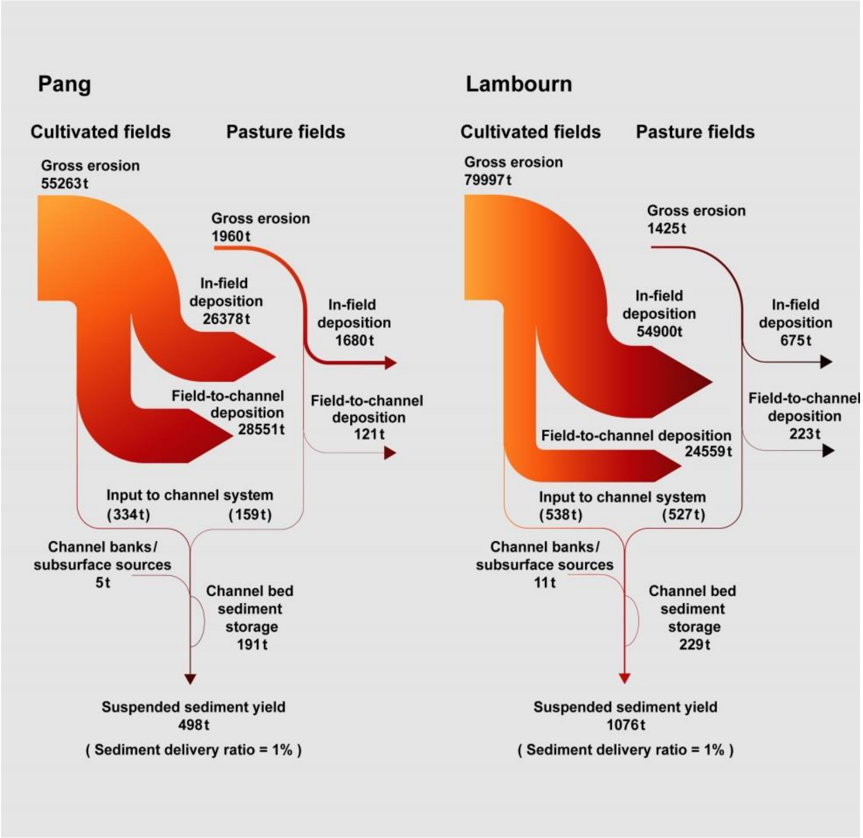

Figure 4 Sediment budgets for the catchments of the Rivers Pang and Lambourn, England. (based on Walling et al. 2006).

6 PERSPECTIVE

The sediment budget of a catchment reflects the interaction of a wide range of controls and will therefore be to some extent unique. However, there is a need to begin to integrate existing knowledge provided by studies such as those outlined above, to provide generalisations as to the likely nature of sediment budgets in different environments.

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