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The potential impact of projected change in farming by 2015 on the importance of the agricultural sector as a sediment source in England and Wales

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ABSTRACT

In association with a major initiative aimed at identifying policy packages for inclusion in the Programmes of Measures (POM's) comprising EU Water Framework Directive (WFD) River Basin Management Plans (RBMP's), recent work has evaluated the gap between current and compliant suspended sediment losses due to farming across England and Wales. The work required national scale sediment source apportionment to assess the current contributions of diffuse agricultural and urban sector losses, channel bank erosion and point source discharges to the total suspended sediment loads delivered to all rivers. Results suggested that the agricultural sector dominates present day (year 2000) sediment inputs to rivers (1929 kt = 76%) compared to eroding channel banks (394 kt = 15%), diffuse urban sources (147 kt = 6%) and point source discharges (76 kt = 3%). Projected change in farming by 2015, represented by the Business as Usual forecast of structural developments and predicted uptake of sediment mitigation methods, suggested an overall 9% reduction in sediment loss from the agricultural sector across England and Wales. The projected reduction is unlikely to deliver sediment compliance in all catchments. Key limitations of the integrated modelling approach are discussed.

1. Introduction

Excessive levels of sediment in river systems are responsible for a number of important environmental problems which continue to rise up the water policy agenda in many countries. Artificially elevated sediment loadings reduce the depth of the photic zone, thereby decreasing both primary and secondary production, with specific impacts including reduced growth and abundance of fish (Sigler et al., 1984; Lloyd et al., 1987) and significant declines in the feeding rate, food assimilation and reproductive potential of benthic invertebrates (McCabe and O'Brien, 1983). Such adverse ecological impacts resulting from enhanced sediment loadings are influenced by a range of factors including, amongst others, the frequency (Shaw and Richardson, 2001) and duration (Newcombe and Jensen, 1996) of exposure. Sediment mobilisation, transport and delivery through river channel systems is also a key vector governing the transfer and fate of nutrients (House, 2003; Collins et al., 2005) and contaminants (Warren et al., 2003; Cave et al., 2005). Sediment-associated fluxes underscore the critical significance of sediment in relation to wider diffuse pollution management issues.

Since 2000, the European Water Framework Directive (WFD; European Parliament, 2000) has established an integrated framework for the baseline level of protecting inland surface, ground, transitional and coastal waters. This over-arching water policy for EU member states establishes a number of key objectives such as protecting and enhancing water ecosystems and achieving 'good ecological status' by 2015. The emphasis on water bodies and river basins as reference units, socio-economic planning and public participation mean that the WFD constitutes a paradigm shift in integrated water policy and management (Hirschfeld et al., 2005; Jessel and Jacobs, 2005; Volk et al., 2009).

Demanding deadlines comprise the timeline of WFD implementation, including the publication of River Basin Management Plans (RBMPs; 2008/9), establishment of Programmes of Measures (PoMs; 2009) and implementation of PoMs (2012). The urgency of policy decisions in relation to sediment problems means that modelling approaches offer a pragmatic method of predicting expected change as a result of management options. Demanding legislative timelines in the immediate short-term, mean that policy decisions for diffuse pollution cannot be delayed for the outcomes of water quality monitoring programmes implemented to measure the environmental impacts of management schemes.

In view of the WFD and alternative national obligations, the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) was launched in April 2006 to provide farmers with dedicated assistance to

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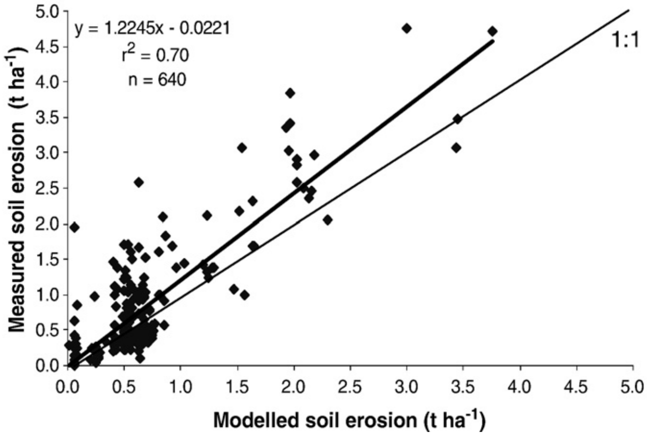

Fig. 1. Comparison of PSYCHIC predictions and measured soil loss at field scale.

help combat the causes of harmful diffuse pollution, including sediment, in 40 priority catchments. Within priority areas, Catchment Sensitive Farming Officers (CSFOs) support farm planning, applications to Environmental Stewardship Schemes launched in August 2005 (e.g. the Entry Level Scheme) and the targeting of capital grant works such as gateway resurfacing to help reduce poaching and sediment mobilisation. Emphasis is on catchment scale appraisal and management (Collins et al., 2007).

In parallel with catchment scale assessments, wider policy support has demanded national scale studies. Accordingly, recent work was commissioned to apportion sediment sources under current environmental conditions (year 2000) and to predict the potential impact of projected environmental change on the importance of the agricultural sector as a national sediment source by 2015. Emphasis was placed on the agricultural sector because recent reform of the Common Agricultural Policy (CAP) has decoupled subsidies from production, making way for a system of Cross Compliance, linking payments to the new terms of Good Agricultural and Environmental Condition (GAEC). Such terms, with respect to soils, include the maintenance of soil structure, organic matter content and vegetation cover to reduce erosion and sediment problems. It was therefore considered important by policy teams to project the impact of expected change in farming on the contribution of agriculture to sediment loss to rivers across England and Wales.

2. Methodology

Assessment of the relative contribution of the agricultural sector to the total sediment load delivered to rivers across England and Wales under current and future environmental conditions, necessitated national scale sediment source apportionment. A novel modelling framework was therefore devised to characterise sediment inputs from the agricultural and urban sectors, channel banks and point source discharges.

2.1. Predicting sediment delivery to rivers from the agricultural sector

National scale sediment delivery to rivers in England and Wales from agriculture was simulated using the prototype process-based PSYCHIC (Phosphorus and Sediment Yield CHaracterisation in Catchments) model (Davison et al., 2008). The hydrological module of PSYCHIC utilises the Mean Climate Drainage Model (MCDM; Anthony, 2003) to estimate evapotranspiration, soil moisture deficit and surface runoff. The MCDM has been tested against water balance tools including MORECS (Hough et al., 1996). Sediment mobilisation is calculated at plot scale using the Morgan Morgan Finney model (Morgan, 2001) and a parameterisation of rainfall erosivity (Davison et al., 2005). Subsequent sediment delivery to watercourses is estimated by attenuating mobilisation on the basis of a source-to-channel connectivity function (McHugh et al., 2002) and a particle size sorting factor based on current understanding (Walling et al., 2000). The presence of field drains is assumed on the basis of the Hydrology of Soil Types (HOST) classification scheme (Boorman et al., 1995) and is deemed an important component of PSYCHIC given that approximately 40% of farmed land in England and Wales is under-drained. National scale statistical datasets (1 km^2 resolution or finer) on a number of input parameters, including climate, slope, drainage density, soil type, land use and cropping and livestock numbers are used to drive the monthly output from PSYCHIC.

Testing output from PSYCHIC using existing information on catchment suspended sediment yields is hampered on account that specific sediment sources, e.g. channel banks, are not represented by the model and due to problems arising from comparing mean climate-based predictions with short-term empirical datasets (Stromqvist et al., 2008). Accordingly, the evaluation of PSYCHIC output has recently focused upon using field scale measurements of soil loss (Evans, 2005). Although this evaluation is ongoing, the results computed for 640 fields (Fig. 1) appear promising, especially given the fact that the variance of the measured data inevitably constrains model performance (cf. Nearing, 2006). Under current environmental conditions, prototype PSYCHIC estimated that the agricultural sector contributes a total of 1929 kt yr^{-1}, equivalent to a national average of 128 kg ha^{-1} yr^{-1} (Fig. 2). Table 1 summarises the PSYCHIC output for the year 2000 in more detail.

2.2. Predicting sediment delivery to rivers from channel banks

National scale sediment delivery to rivers from eroding channel banks was estimated using a prototype national scale index. The bank erosion index was founded on the calculation of river regime and the

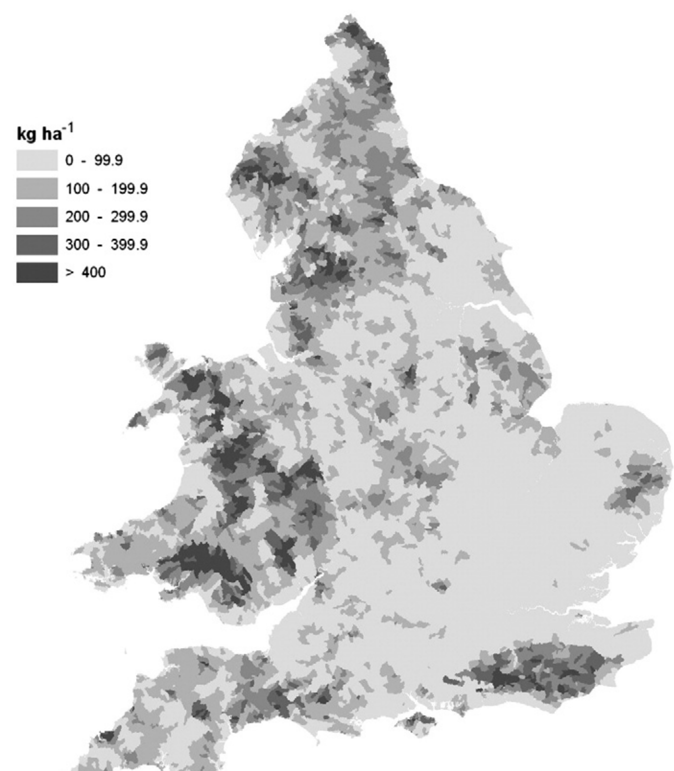

Fig. 2. Sediment delivery to rivers across England and Wales under current environmental conditions simulated using prototype PSYCHIC.