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Uncertainty estimation in sediment fingerprinting un-mixing models: impact of source characterisation and complexity

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Sediment fingerprinting techniques are being applied more frequently to inform soil and water management issues. Identification of sediment source areas and assessment of their relative contributions are essential in targeting cost-effective mitigation strategies. Sediment fingerprinting utilises natural sediment properties (e.g. chemical, magnetic, radiometric) to trace the contributions from different source areas by 'unmixing' a catchment outlet sample back to its constituent sources. Early qualitative approaches have been superseded by quantitative methodologies using multiple (composite) tracers coupled with linear programming.

Despite the inclusion of fingerprinting results in environmental management strategies, techniques are subject to potentially significant uncertainties. Intra-source heterogeneity, although widely recognised as a source of uncertainty, is difficult to address, particularly in large study catchments, or where source collection is restricted. Inadequate characterisation may result in the translation of significant uncertainties to a group fingerprint and onward to contribution estimates. Franks and Rowan (2000) developed an uncertainty inclusive un-mixing model (FR2000+) based on Bayesian Monte-Carlo methods. Source area contributions are reported with confidence intervals which incorporate sampling and un-mixing uncertainties. Consequently the impact of uncertainty on the reliability of predictions can be considered. The aim of this study is to determine the impact of source area sampling resolution and spatial complexity on source area contribution estimates and their relative uncertainty envelope.

High resolution source area sampling was conducted in a 10 km2 intensive grassland catchment in Co. Wexford, Ireland, according to potential field and non-field sources. Seven potential source areas were sampled; channel banks (n=55), road verges (n=44), topsoils (n=35), subsoils (n=32), tracks (n=6), drains (n=2) and eroding ditches (n=5), resulting in 179 samples. End-of-catchment suspended sediments were collected from a network of nested time-integrated samplers. Contributing catchment areas were 0.75 – 10 km2 and samples were emptied every 6-12 weeks. Soil and sediment samples were dried at 40ºC, manually ground and sieved to 125 μm in order to account for particle size enrichment from source to sink. Mineral magnetic measurements were used to characterise each sample. Magnetic susceptibility (high and low frequency), an-hystereic and isothermal remanence (40 mT, 100 mT, 300 mT and 1 T) were conducted and various ratios describing magnetic grain size and character were established. Multivariate factor analysis determined distinct land- and non-field sediment groups and further discrimination between sub-groups.

Source area contributions and uncertainty estimations are reported from the FR2000+ model. Firstly, the model is applied to each nested sub-catchment to identify the effect of increasing source area complexity on source estimations. Secondly, source area sampling resolution is reduced under repeated model runs to determine the significance of source characterisation on uncertainty estimates and consequently identify minimum methodological requirements.