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The use of visible and near-infrared reflectance measurements for identifying the source of suspended sediment in rivers and comparison with chemical fingerprinting

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The transport of sediments in rivers may lead to a series of problems such as flooding, siltation of reservoirs and channels, pollution by sediment-fixed contaminants and degradation of aquatic habitats. Therefore there is a need for a reliable technique that allows to determine the source (origin) of that sediment. However, the complex interactions of sediment mobilization and delivery and the spatial and temporal variations make the process difficult to assess. In addition, there are large costs associated to the long-term monitoring of large scale river basins.

The fingerprinting technique is known to be a good and reliable technique for sediment source determination in river catchments. Several studies have used various chemical and physical sediment properties for fingerprinting sediment sources. A composite fingerprint property in combination with a multivariate mixing model is needed to determine the quantitative contribution of the sources, and this procedure has been successfully applied to a range of environments. However, some methodological constraints hamper the application of this technique. Cost and labour for the analysis of potential sources and suspended sediment samples for a range of properties can be very high. Also the statistical procedure does not take into account the inherent variability of the properties of the different sediment sources. Another constraint is that the degree of uncertainty associated with the numerical solutions of the mixing model cannot be calculated. Therefore, fingerprinting using visible and near-infrared reflectance measurements may be an alternative way of determining sediment sources in river catchments. These measurements have to be coupled with advanced multivariate statistical methods like partial least squares (PLS) regression analysis. The PLS regression allows to calculate a confidence interval of the predicted sediment contributions.

In this study, two techniques of fingerprinting were evaluated in order to estimate the relative importance of the primary potential sediment sources within two headwater catchments of the Gilgel Gibe river in Southwestern Ethiopia. The two headwater catchments (Unta and Desera) were both analysed with the same techniques in order to find differences and agreements. The first technique applied was a quantitative composite fingerprinting technique using chemical analysis of suspended sediment samples and soil samples (potential sediment sources). To quantify the sediment source contributions a numerical mixing model was used in conjunction with the composite fingerprint. During the study period (August-September 2009), the mean relative contributions at the catchment outlet were (as fraction): top soil (0.42) and landslides (0.58) for the Unta catchment and top soil (0.16) and landslides (0.84) for the Desera catchment. The second technique is based on the measurement of visible and near infrared reflectance (vis-NIR, wavelength 350-2500 nm) of suspended sediments and source samples. The calculation of sediment source contributions was assessed using a PLS regression model. The results confirmed that vis-NIR reflectances show linearly additive behaviour and this can be used in mixing models. The agreements between the results of the classical technique based on chemical fingerprint properties and the technique based on vis-NIR reflectances were excellent for the Unta catchment (R2=0.946) but poor for the Desera catchment (R2=0.364). The Root Mean Square Error of Prediction of the model was 0.067. Both techniques revealed that top soil erosion played an important role during peak flow discharges. The quantitative composite fingerprinting technique using spectral signatures from both sediment sources and suspended sediment samples provided a faster and more cost effective alternative to the classical procedure.