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Accuracy of mixing models in predicting sediment source contributions

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ABSTRACT

Determining the source of sediment using geochemical properties is now a widely used approach in catchment management. However the outcome of these studies often depends on the type of model used to determine the relative contribution from difference sources. Here we test the accuracy and robustness of four widely used sediment mixing models using artificial mixtures of three well-distinguished geologic sources. Sub-samples from these three sources were mixed to create four groups of samples, each consisting of five samples, with known source contributions, 20 samples in total. The source contributions to the individual and groups of artificial sediment mixtures were calculated using each of the four mixing models: Modified Hughes, Modified Collins, Landwehr and Distribution models. Unlike Modified Collins and Landwehr models which use calculated values from each tracer property of individual sources (e.g. mean and standard deviation), Hughes model uses the measured fingerprint property of replicated samples from each source and Distribution model incorporate distribution of tracers and correlation between tracer properties for sediment samples and sources. For the 20 individual sample mixtures the Distribution model provided the closest estimates to the known sediment source contribution values (Mean Absolute Error (MAE) = 10.8%, and standard error (SE) = 0.9%). The Modified Hughes (MAE = 13.5%, SE = 1.1%), Landwehr (MAE = 19%, SE = 1.7) and Collins models (MAE = 29%, SE = 2.1%) were the next accurate models, respectively. For the groups of the samples the Modified Hughes was the most robust source contribution predictor with 5.4% error. The Distribution model (MAE = 6.1%) and Landwehr model (MAE = 7.8%) were the second and third accurate models. Collins model with MAE of 28.3% was a significantly weaker source contribution predictor than the three other models. This study demonstrates the dependence of source attribution on model selection. The study highlight the need to test mixing model using known source and mixture samples prior to applying them to field samples. The results indicate that the Distribution and Modified Hughes models provided the most accurate source attributions using geochemical fingerprint properties.

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1. Introduction

Sediment geochemistry has been widely used to identify the spatial sources of sediments delivered to waterways (Olley and Caitcheon, 2000; Hardy et al., 2010; Weltje and Brommer, 2010). Determining the spatial source of transported sediments with sediment tracing involves measuring sediment properties that are capable of distinguishing sediments derived from different areas of the catchment (Collins et al., 1996, 1998; Hancock and Pietsch, 2008). The geochemical characteristics of eroded sediments are strongly influenced by those of the soils and ultimately the rock-types from which they are derived (Klages and Hsieh, 1975; Caitcheon et al., 2006). Different underlying parent rock materials often results in spatial sources with distinct geochemical compositions (Olley et al., 2001; Motha et al., 2002; Douglas et al., 2009). Sediments eroded from soils derived from a particular rock type often maintain these distinct geochemical properties during sediment generation and transport processes (Caitcheon et al., 2006; Hughes et al., 2009). Determining the contribution of different sources to downstream sediments using the geochemistry of the sediments invariable involves the use of a multivariate mixing model. However the accuracy of these models has rarely if ever been tested. Haddadchi et al. (2013) compared mixing models applying local and global optimization methods to datasets from two different catchments. The results indicated that the mixing model outputs could change remarkably depending on which mixing model was used.

Here we used an experimental approach to test the accuracy and robustness of four widely used sediment mixing models applying artificial mixtures of three well-distinguished geologic sources. Sub-samples from these three sources were mixed to create four groups of five samples with known source contributions, 20 samples

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in total. The four mixing models tested were: Modified Collins (Collins et al., 2010a), Modified Hughes, Landwehr (Devereux et al., 2010; Haddadchi et al., 2014) and Distribution (Laceby and Olley, in press) models. These models are described below. Our aim is to find which of these most accurately predicts source contribution.

2. Materials and methods

Five source samples were collected from each of three distinct rock types in the Emu Creek catchment, South East Queensland, Australia. Particle size and organic matters are potential factors that may affect tracer properties (Smith and Blake, 2014). To minimize the effect of changes in particle size distributions on the geochemistry the less than 10 μm sediment fraction was separated using settling method based on Stokes's law. This resulted in five <10 μm samples from each of the three rock-types. The source samples were then oven-dried at 60 °C temperature. A two decimal place balance was used to measure the precise proportion of source samples based on their weight. The samples were manually disaggregated using a pestle and mortar. These were then completely mixed to create a set of samples with known source contributions. Fig. 1 shows diagrammatically the process involved. Four groups of samples of known source contributions were created:

Group 1: the same weights (10 g) of randomly selected samples from each source types were mixed to make five artificial sediment samples (M1 to M5). The three source types, Main Range Volcanic (MRV), granite and mafic each made a contribution of 33.33% to

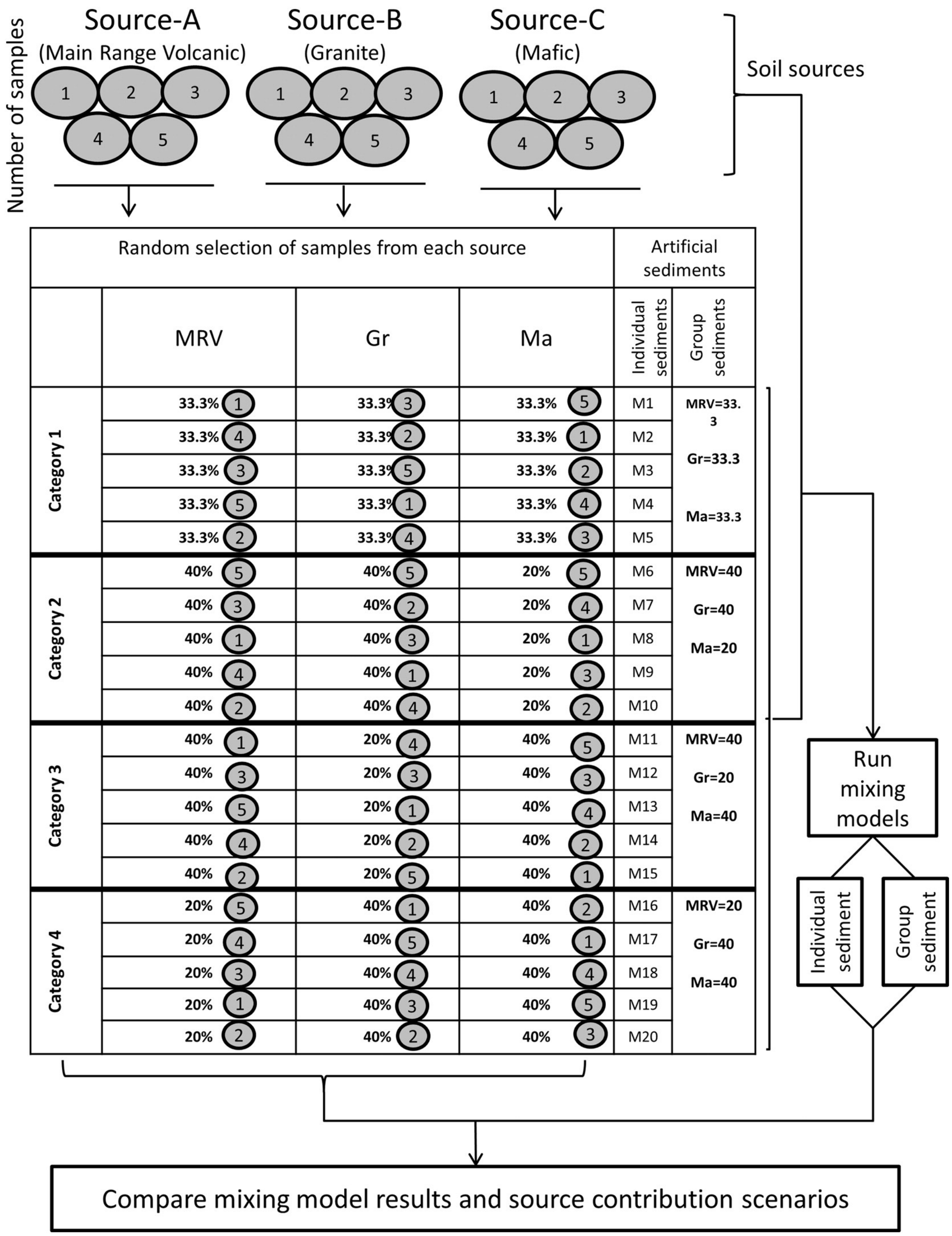

Fig. 1. The sketch of study to test the accuracy of mixing models using given source proportion of artificially made sediments.

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