Improving spatial representation of erosion sources using Sediment Fingerprinting with terrain data and sediment budget modelling

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Background

Sediment fingerprinting has received considerable research focus since its inception with advancements made in tracer availability and selection, source discrimination, mixing model optimization and source quantification. Despite these advancements and numerous demonstrations of its use, sediment fingerprinting has struggled to receive widespread uptake and impact for end-users. Barriers to uptake include lack of understanding, high costs and limited spatial scale of application. Here, two conventional datasets are used to show how integrating sediment fingerprinting results with spatial datasets and modelling can enhance interpretation of source apportionment results and improve the utility of this information for end-users focused on the spatial targeting of erosion sources for mitigation to reduce downstream sediment impacts.

Methods

Sediment sources were sampled and characterized by distinct geomorphic units representing sediment erosion processes for two separate studies:

1) Oroua river catchment. Analysed geochemical and radionuclide tracers on < 63-µm and 125–300-µm size fractions to represent fine and coarse sediment. An optimum fingerprint was selected using standard techniques and a frequentist model was used to determine the dominate source contributions to overbank sediment deposits (Fig. 2; Fig. 3).

- Source loads were derived from the proportion of total sediment load estimated from SedNetNZ (550,000 t yr^{-1}; Dymond et al. 2014) and distributed to the spatial extent of the source to provide sediment yield (Fig. 4).

2) Manawatu river catchment. Analysed geochemical tracers on < 63-µm size fraction to determine source proportions and sediment dynamics occurring at hourly intervals during a 53 hr flood event. An optimum fingerprint was selected using standard techniques and a Bayesian model was used to determine the dominate source contributions to different phases of the flood hydrograph.

- Source loads were derived from the proportion of total sediment load estimated from a network of gauged sites across the major sub-catchments and applied to their mapped spatial area weighted for slope.

Results & Conclusions

Sediment sources were characterized and using geochemical tracers and estimated the dominant sediment sources contributing to downstream sediment in:

1) Oroua river catchment for overbank sediment deposition for each particle size (Table 1). The sediment sources for both <63 µm and 125–300 µm shows Hill Subsurface (31–37%) and Unconsolidated sediment sources (26–27%) provide the dominate sources (Fig. 3).

- The highest specific sediment yield source originates from Unconsolidated (1,928–2,151 t km^{-2} yr^{-1}) followed by Mudstone (1,131–1,257 t km^{-2} yr^{-1}), Hill Subsurface (953–1,138 t km^{-2} yr^{-1}), Mountain Range (589–981 t km^{-2} yr^{-1}), and Hill Surface (52–60 t km^{-2} yr^{-1}). Channel Bank potentially provides up to 220 t km^{-1} y^{-1} (Fig. 4).

2) The Manawatu river catchment for source proportions contributing to hourly suspended sediment samples (Fig. 5; Fig. 6; Fig. 7; Table 2) and that distributing the sediment load proportions according to the spatial extent of the source area provides a visual representation of the original erosion source occurring through a storm event.

- The spatial distribution (Fig. 8) shows at 3-hrs, the sediment pattern is mostly from the Pohangina, with the highest yields of 0.009 kg m^2 h^{-1} coming from areas where dominant sources overlap with the steepest slopes. At 14-hrs, Mudstone source increases as the dominant proportion, along with small Hill Subsurface peak coinciding with beginning of sediment arrival from the Upper Manawatū. At 35-hrs, the sediment is almost entirely originating from the Upper Manawatū, continuing to originate from steep hill country.

The Oroua catchment study applied source loads uniformly while the Manawatu example applied the load using a slope weighted model. Applying spatial models to sediment fingerprinting derived source proportions can provide much useful outputs for end-users.

1) Oroua River Catchment

Fig 1. a) Mudstone source, b) Hill Subsurface source, c) Overbank sediment deposit.

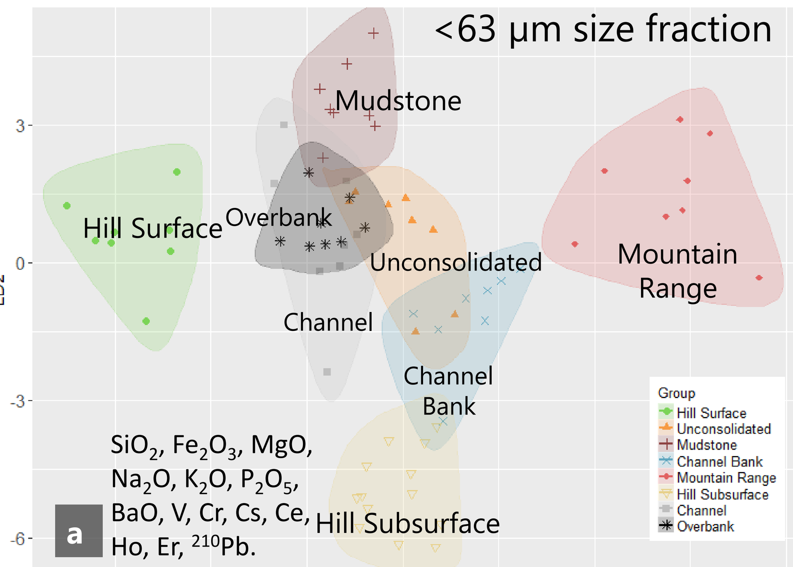

Fig. 2 Discrimination Function Analysis of selected tracers for <63 µm size fraction

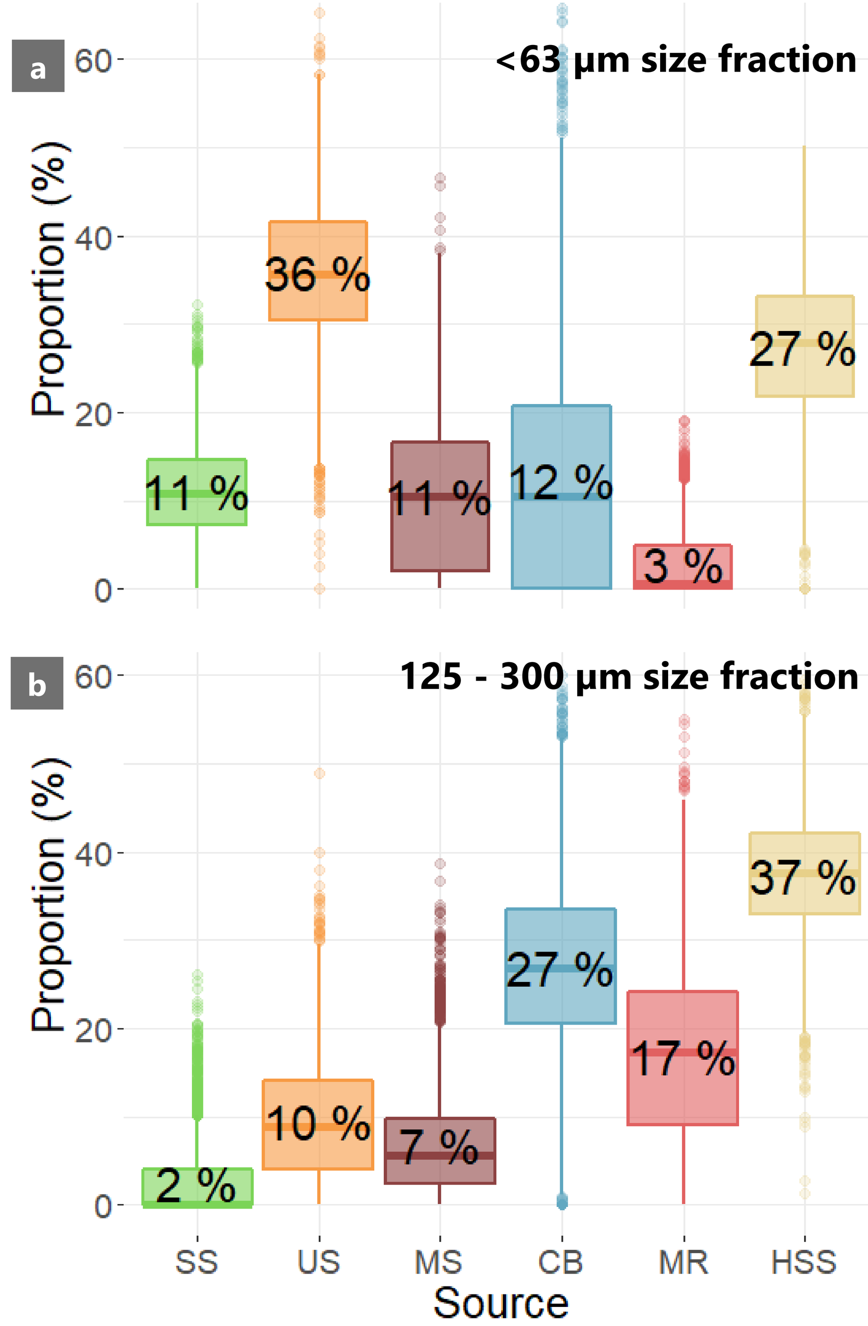

Fig. 3 a) Sediment source proportions for <63 µm size fraction; b) and 125–300 µm size fraction

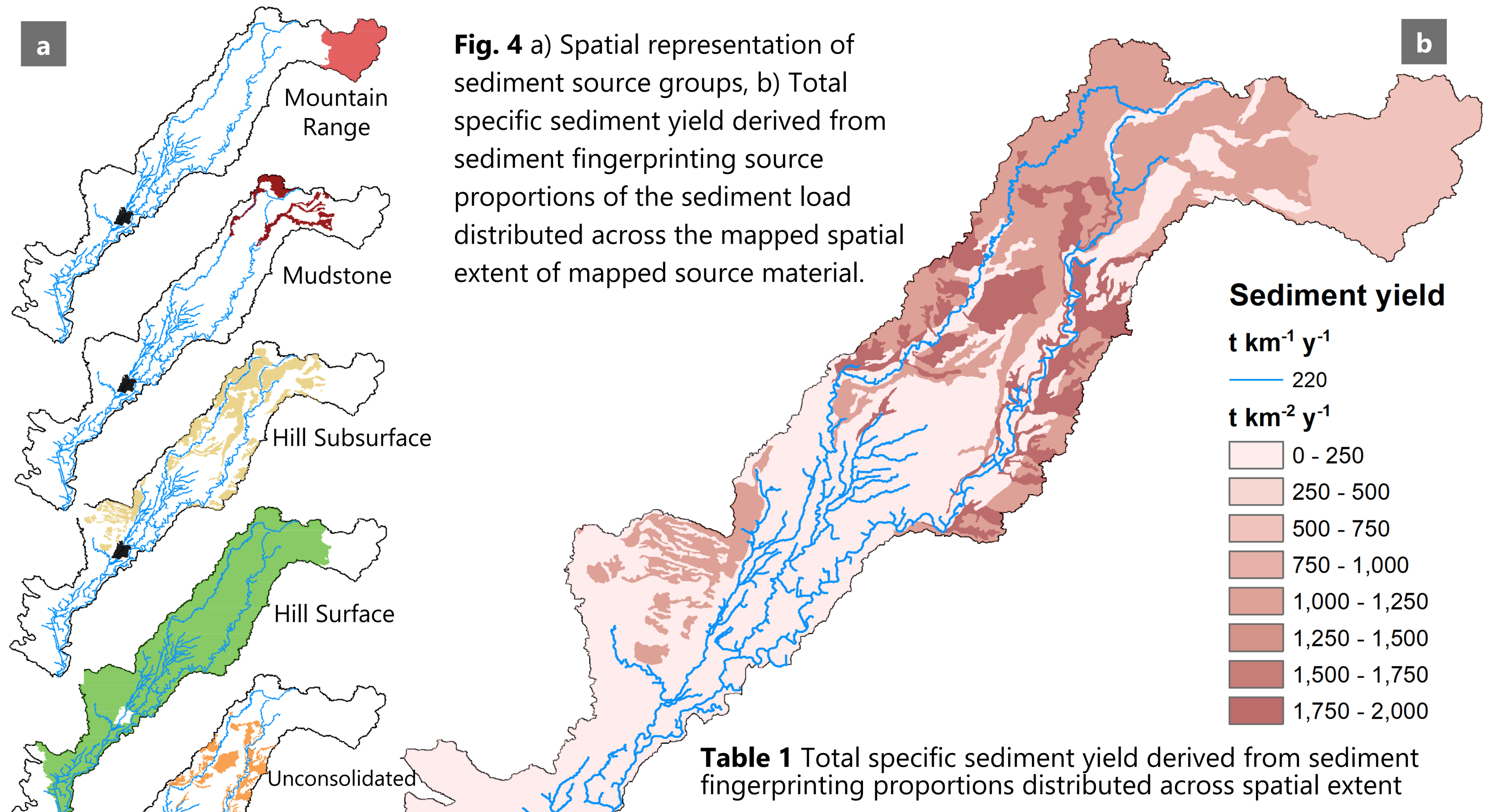

Fig. 4 a) Spatial representation of sediment source groups, b) Total specific sediment yield derived from sediment fingerprinting source proportions of the sediment load distributed across the mapped spatial extent of mapped source material.

Table 1 Total specific sediment yield derived from sediment fingerprinting proportions distributed across spatial extent

Sources	%		
	< 63 µm	125–300 µm	Total Combined
Hill Surface (SS)	11	2	7
Unconsolidated (US)	36	10	26
Mudstone (MS)	11	7	9
Channel Bank (CB)	12	27	18
Mountain Range (MR)	3	17	9
Hill Subsurface (HSS)	27	37	31

2) Manawatu River Catchment

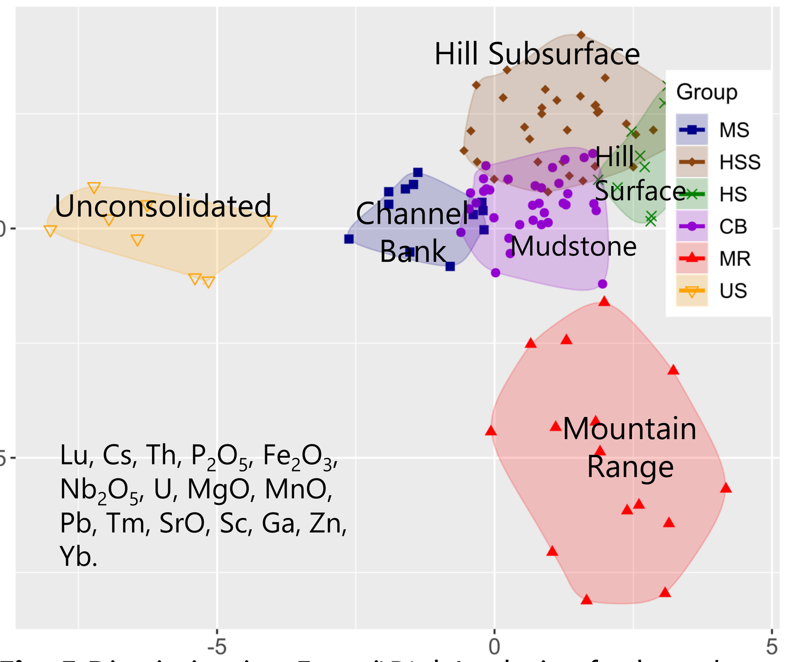

Fig. 5 Discrimination Functional Analysis of selected tracers for <63 µm size fraction

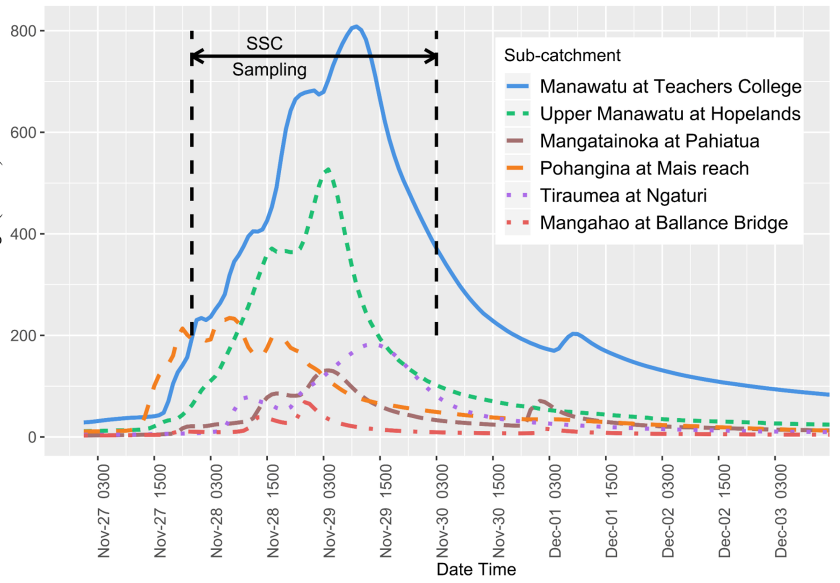

Fig. 6 Flood Hydrograph showing sub-catchment hydrographs

Source	Mean Proportion (%)			Sediment Load (t)		
	Rising Limb	Falling Limb	Total Event	Rising Limb	Falling Limb	Total Event
Mudstone (MS)	46.4	54.4	48.8	36,962	14,676	51,638
Hill Subsurface (HSS)	7.5	7.8	7.6	6,551	2,077	8,628
Hill Surface (HS)	4.4	4.3	4.4	3,769	1,192	4,962
Channel Bank (CB)	6.1	6.3	6.1	5,107	1,866	6,973
Mountain Range (MR)	28.3	21.8	26.3	20,550	6,276	26,825
Unconsolidated (US)	7.3	5.5	6.7	4,728	1,590	6,319

Table 2 Mean Source Proportions and Sediment Loads for Rising Limb, Falling Limb and Total Event.

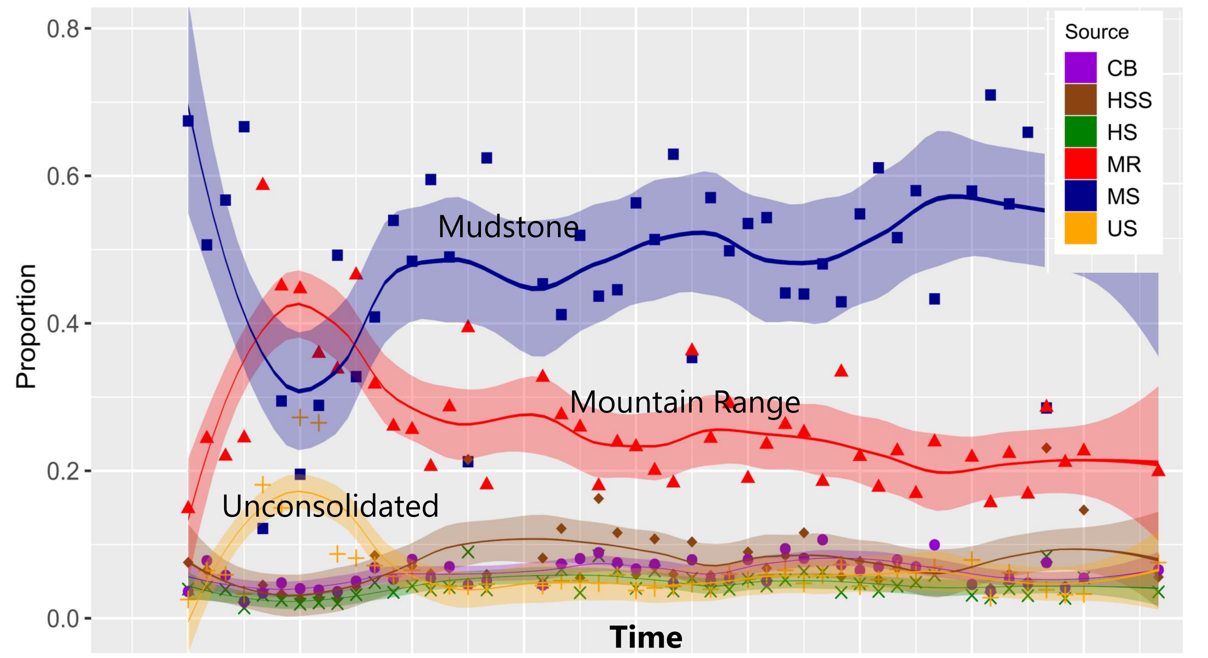

Fig. 7 Mean proportions of each sediment source throughout the storm event plotted against time.

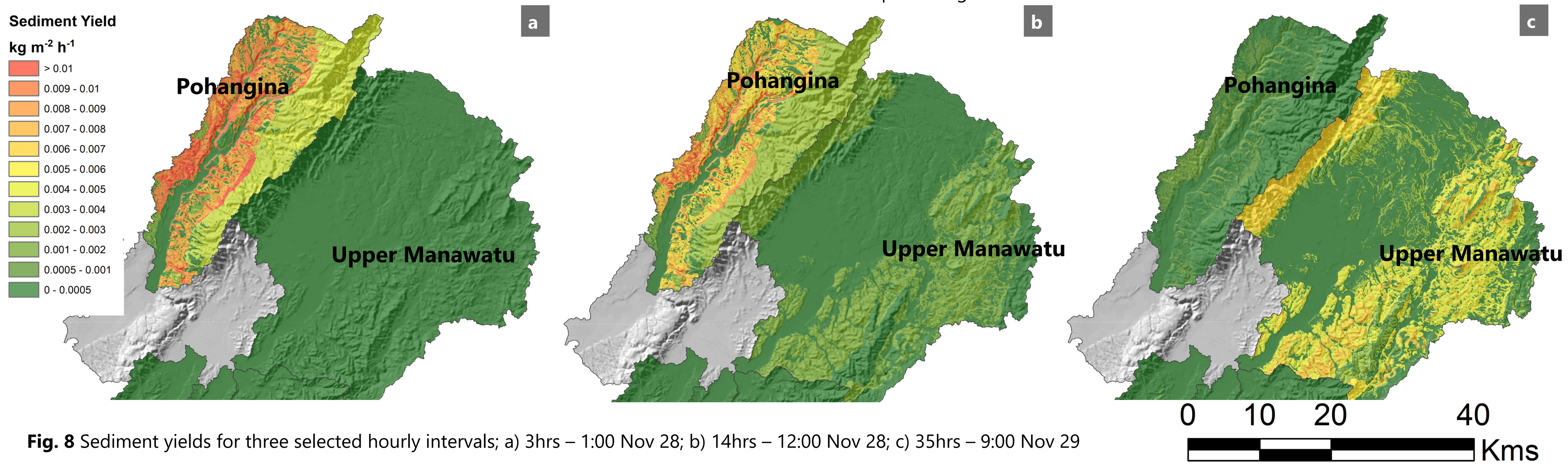

Fig. 8 Sediment yields for three selected hourly intervals; a) 3hrs – 1:00 Nov 28; b) 14hrs – 12:00 Nov 28; c) 35hrs – 9:00 Nov 29