SAFE Project Workshop, Imperial College Silwood, 2nd October 2014

SAFE hydrology: progress in assessing the impacts of varying land-use history on water pollution, channel size, erosion and downstream sedimentation in the upper Brantian and Kalabakan catchments

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Structure of the Presentation

Catchment monitoring of hydrological impacts (suspended sediment, solutes and discharge) of land-use change and riparian widths – covered by Anand; here progress is reported in:

1. Some remarks about rainfall at SAFE and rainfall change in the region

2. Variations in nitrate and phosphate levels in streamwater with land-use

3. Initial progress of a nested catchment sediment fingerprinting and dating approach to assessing the history of change in sediment sources, rates of sedimentation and upstream erosion in relation to logging and land-use change

4. Channel size and shape in response to logging and oil palm conversion

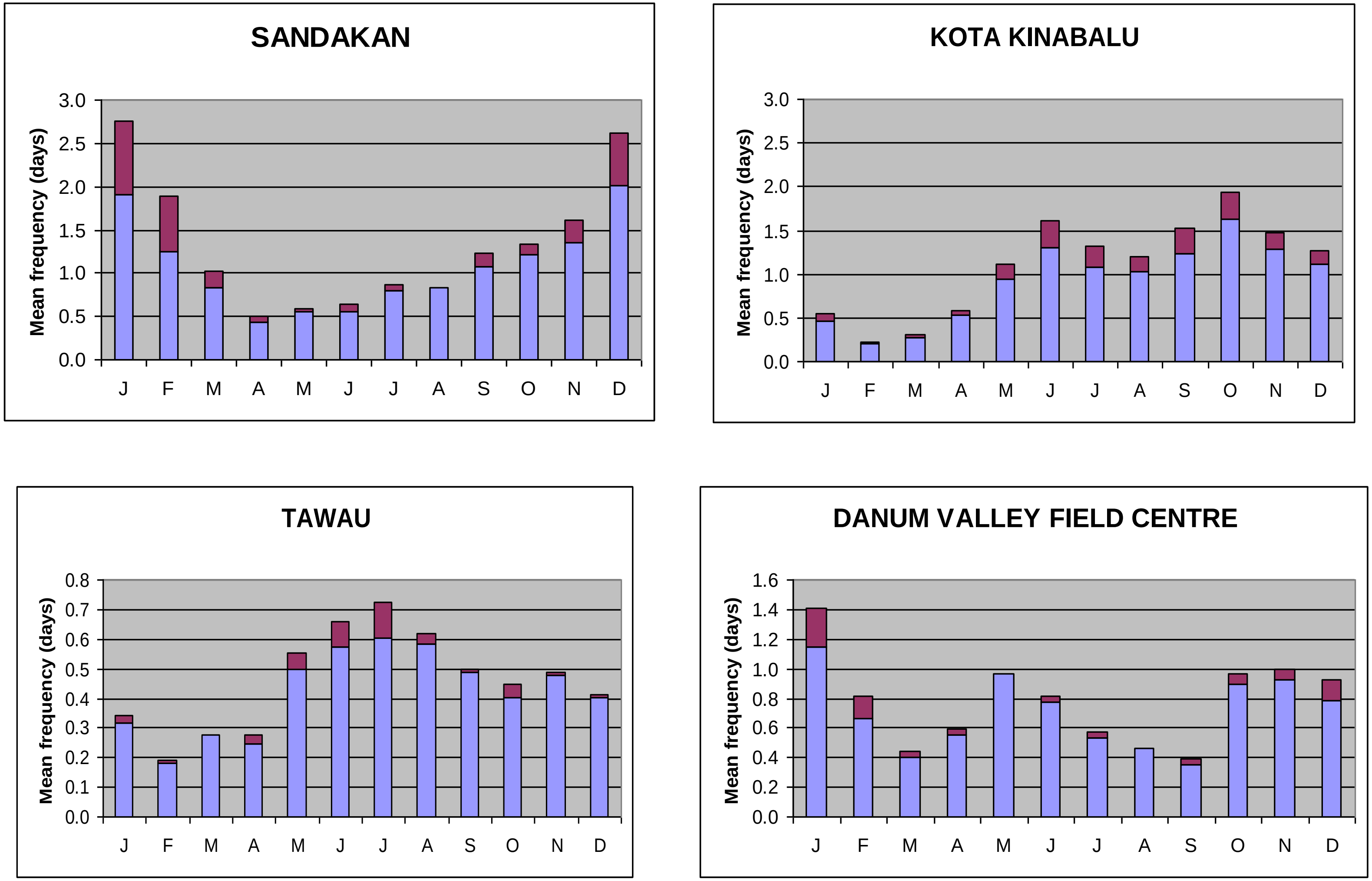
1. Rainfall at SAFE and rainfall changes

Records kept by Rebecca at SAFE Base Camp, catchment raingauges at gauging stations and analysis of historical data

Annual Rainfall and Heavy Daily Falls >50 mm at Old and New SAFE Base Camps compared with Danum July 2011 - June 2014

Year	OLD SAFE AR mm	NEW SAFE AR mm	DANUM VALLEY AR mm	OLD SAFE >50 mm	NEW SAFE >50 mm	DANUM VALLEY >50 mm
2011-12	2731	nd	3204	4	nd	13
2012-13	2569	nd	3245	7	nd	6
2013-14	nd	2486	2999	nd	8	13
Mean 1985-2014			2888			9.4

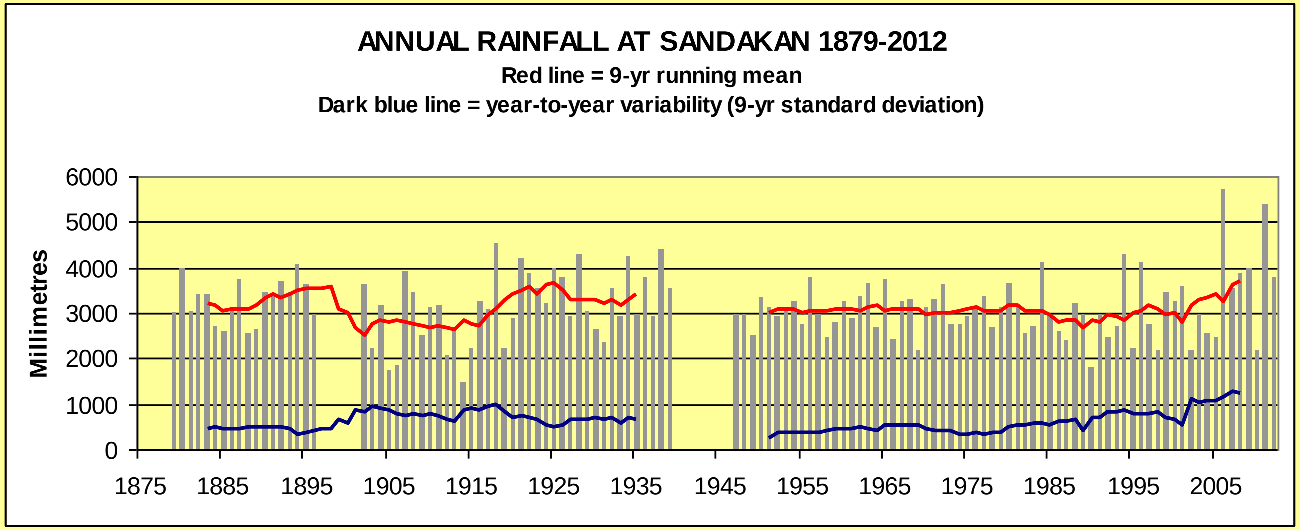
- **Annual rainfall is lower than at Danum, but higher than at Tawau (mean annual rainfall 1862 mm)**
- **Annual rainfall is higher at the New SAFE Base Camp than at the Old Base Camp**
- **Future analysis will estimate the difference by comparing with records at Catchment Gauging Station raingauges**
- **The highest recorded daily rainfalls are 76.8 mm at the Old Camp on 1st March 2013 and 90.0 mm at the New Camp on 16th April 2014**

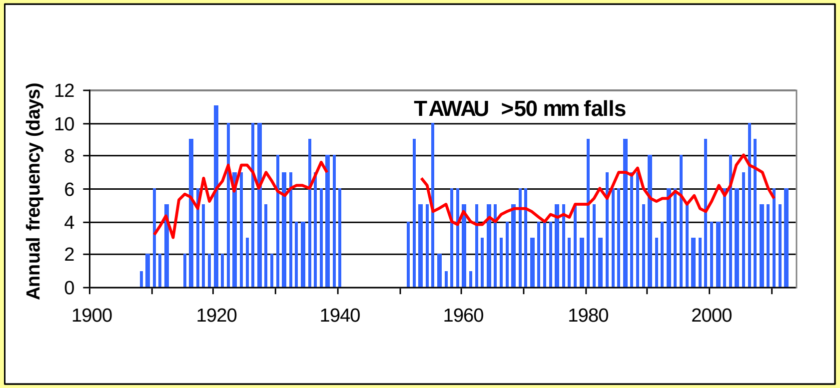


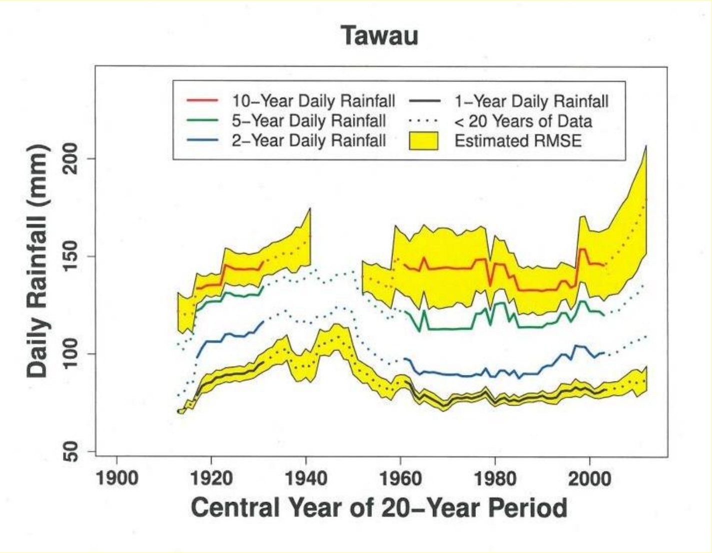
Mean annual frequency of daily rainfalls > 50 mm (blue) and >100 mm (purple) at stations in Sabah (Walsh et al. 2013). Note largest rainstorms at Tawau (and perhaps also SAFE) occur in the summer SW Monsoon in contrast to Danum and Sandakan

Land-use impacts are being assessed against a background of increasing annual rainfall and magnitude-frequency of large rainstorms in Sabah including at Tawau (Walsh *et al.* 2013)

Note that at Tawau it is the larger daily rainfalls of longer return period that are increasing most (BOTTOM RIGHT). These are SW monsoon thunderstorms







2. Nitrate and phosphate levels of streamwaters

Project monitoring + undergraduate dissertation project of Laura Murphy (fieldwork July 2014)

Nitrate and Phosphate Concentrations for the SAFE catchments April 2011 – January 2014: note the low NO_3 of the OP catchment

Data (mg/l) from 3-weekly sampling programme; n= 26 to 33 (except OP, n = 17)

Catchment	Land-use	NO_3 Max	NO_3 Min	NO_3 Mean	PO_4 Max	PO_4 Min	PO_4 Mean
VJR	Old Regrowth	0.80	0.20	0.52	0.24	0.02	0.09
LFE	Twice logged	1.23	0.20	0.58	0.36	0.02	0.10
0m	Multiple logged	1.23	0.30	0.55	0.29	0.03	0.11
5m	Multiple logged	0.90	0.20	0.58	0.39	0.04	0.14
15m	Multiple logged	8.20	<LD	0.97	0.21	0.04	0.11
30m	Multiple logged	1.10	0.40	0.62	0.16	0.02	0.07
60m	Multiple logged	0.80	0.30	0.53	0.33	0.03	0.13
120m	Multiple logged	0.80	0.20	0.64	0.34	0.03	0.11
OP	Oil palm	1.50	0.30	0.74	0.26	0.02	0.06

Anion results (mg/l) of a spatial water chemistry survey of oil palm catchments in the upper Brantian region in July 2014

Catchment	Fluoride	Chloride	Nitrate	Phosphate	Sulphate
Gaharu	0.04	1.98	1.40	<LD	1.92
Keruing	0.03	2.12	3.61	<LD	3.45
Merbau	0.05	2.33	2.79	0.04	3.91
Brantian NE	0.03	2.43	2.39	0.09	4.33
Smaller NE tributary	0.07	3.73	1.16	<LD	2.71
Oil Palm Mill NE tributary	0.07	28.58	0.06	0.07	0.21
Brantian NW	0.06	3.25	2.77	<LD	4.30
OP 11	0.05	6.59	2.63	<LD	21.38

- Nitrate levels vary, but are mostly much higher than in the OP catchment and the logged forest catchments
- Nitrate levels are NOT high compared with arable areas of SE Britain and Continental Europe
- Reason may be a combination of dilution by the high rainfall and efficiency of take-up of fertilizer application
- The variation in NO_3 may reflect variations in riparian forest, fertilizer application methods and oil palm age
- The tributary containing an oil palm mill is low in nitrate/phosphate, but high in chloride – any ideas why?

3. Reconnaissance work on applying a hierarchical sediment fingerprinting/dating approach to assessing changes in sedimentation and sediment sources with land-use history – using fluvial sediment cores

NERC Ph.D. project of Sam Higton (2014 onwards) + undergraduate dissertation project of Jake Marshall - fieldwork July 2013)

Sediment fingerpinting/dating approach

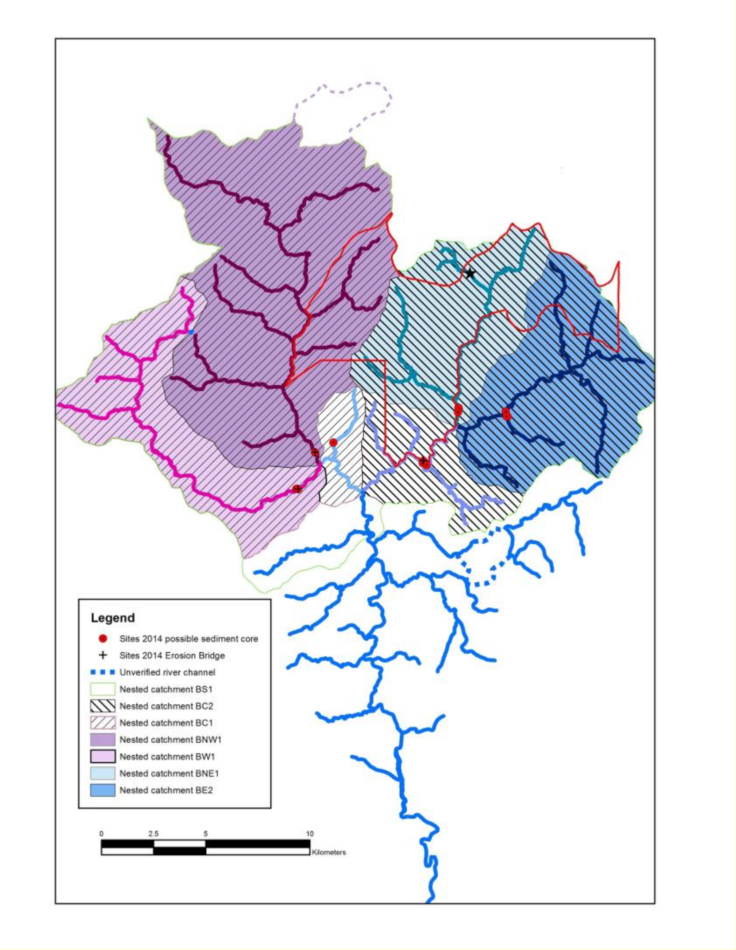
PRINCIPLES

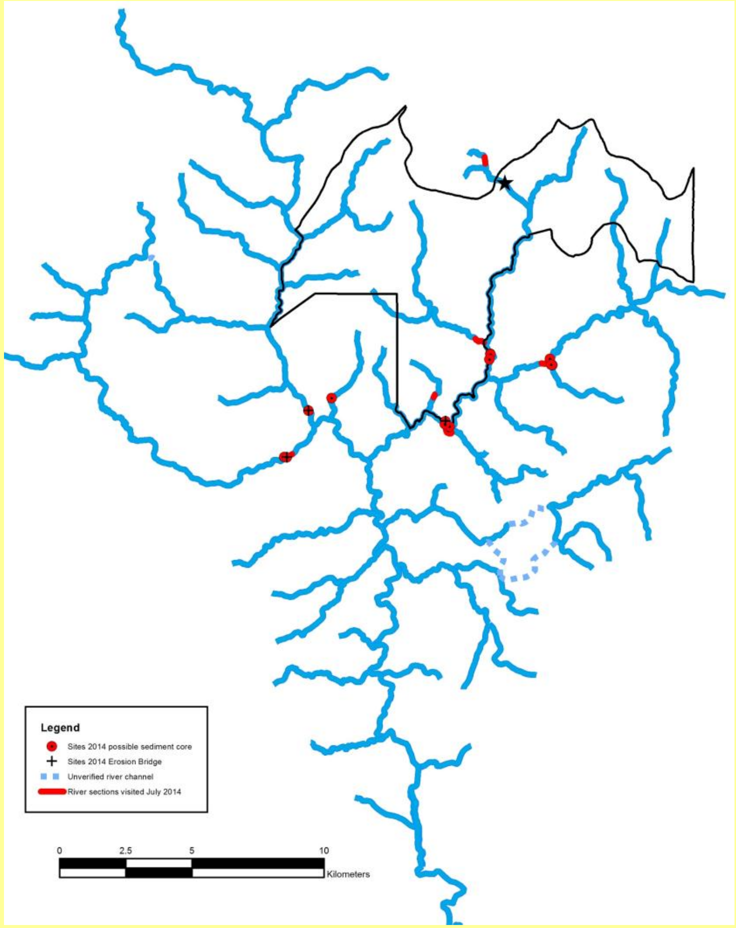
- Sediment fingerprinting involves quantifying contributions of upstream sediment sources to downstream sediment budgets by using distinctive sediment properties of the upstream sources (spatial and/or vertical)
- Use of downstream sediment cores allows one to detect and quantify changes through time over the timespan of the core
- Upstream cores allow for changes in properties of upstream sources with logging or and-use change
- Cores can be dated by Pb-210 and Cs-137 isotope analysis and potentially use of oil palm biomarkers denoting the date of conversion upstream

PROCEDURE AT SAFE

- The catchment/sub-catchment hierarchical approach at SAFE incorporates comparisons of geochemical signatures of upstream and downstream fluvial cores
- Progressive sedimentation at cores is assumed – and will be tested via real-time monitoring via stake-and-washer erosion bridge transects
- Use of a combination of CORES and REAL-TIME ACCRETION is designed to yield historical and current records of changes in sedimentation rates/sediment sources respectively

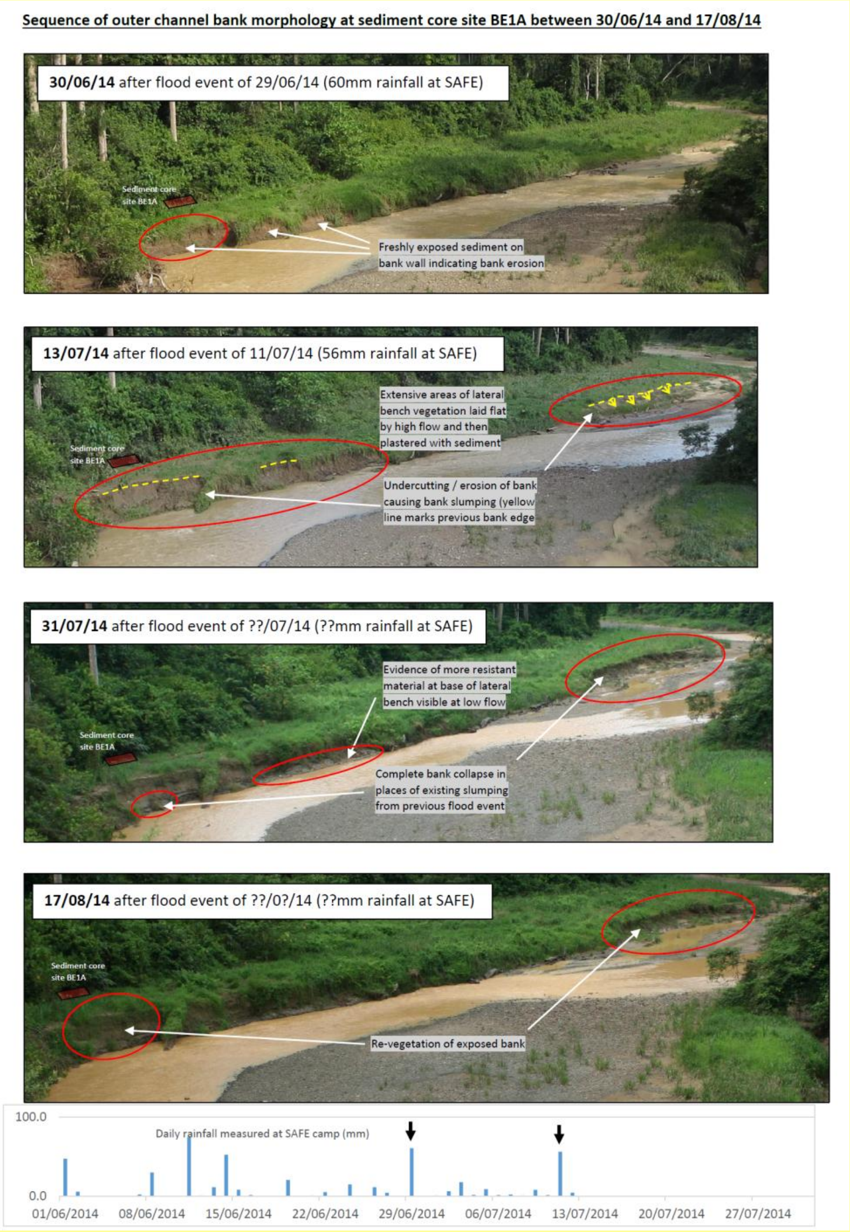
Reconnaissance of riparian zone of the upper Brantian has identified suitable ‘progressive sedimentation’ (NOT ‘come-and-go’) sites for historical fluvial cores and real-time deposition monitoring in the logging/clearance/conversion phase



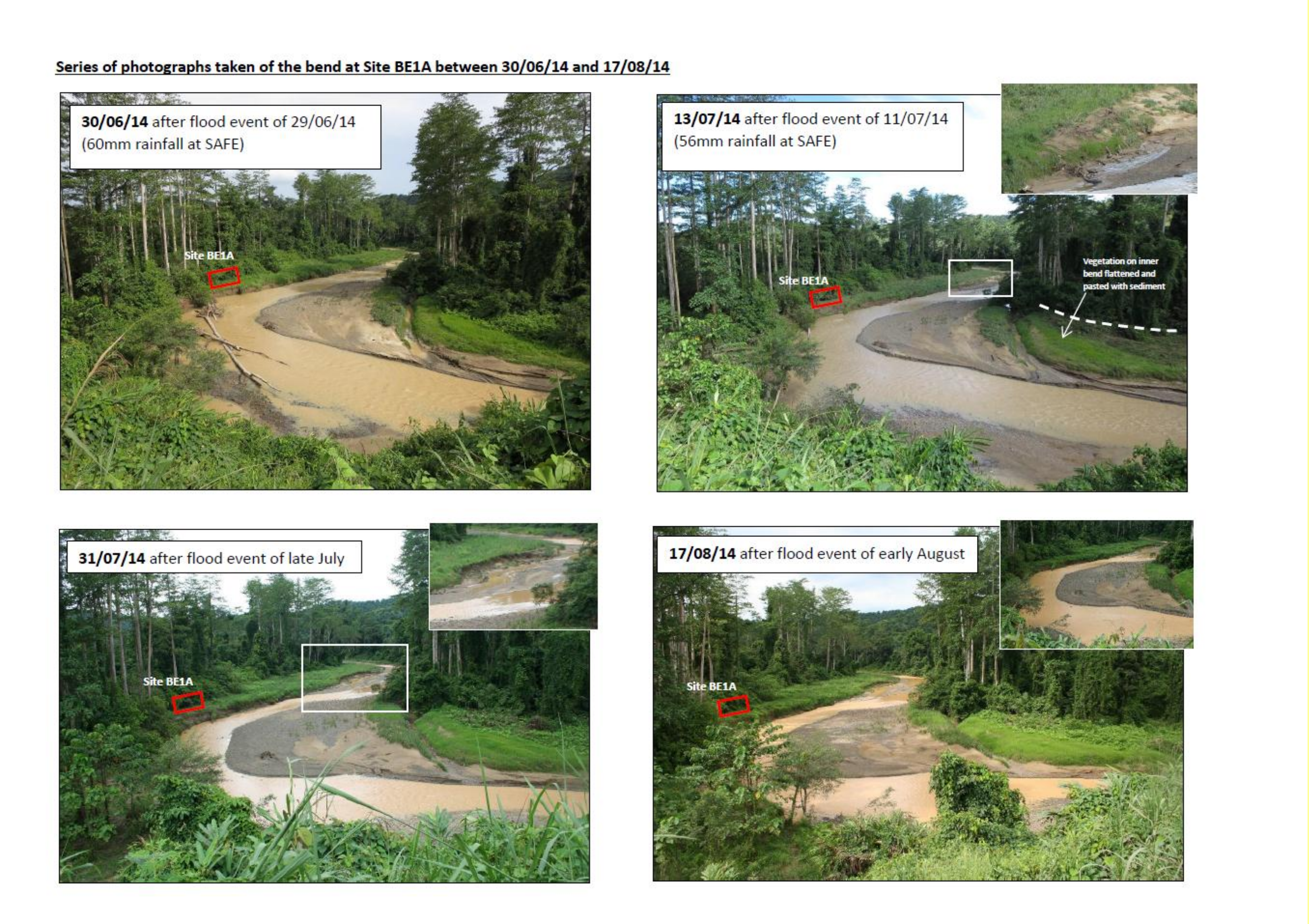


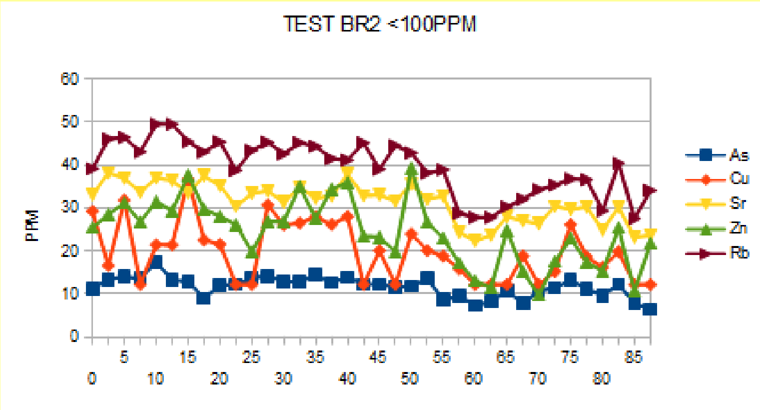
Brantian NE Meander

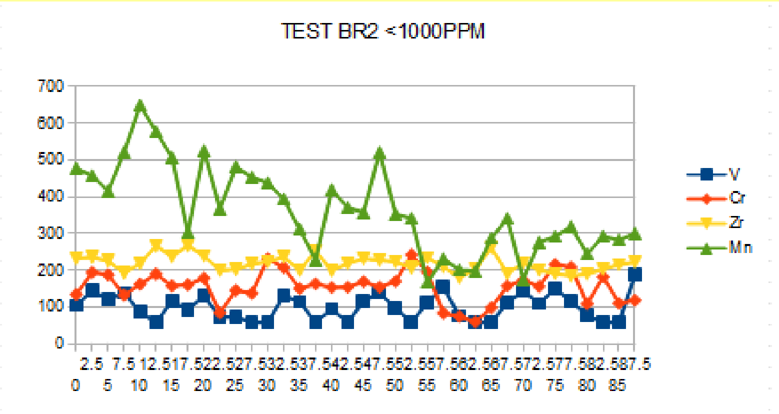
- Site on lateral bench identified + pit samples and 0.85 m core taken in summer 2013
- Site instrumented with an erosion bridge (stake-and-washer) transect in June 2014 to assess integrity as progressive sedimentation site
- ‘Immediate’ flood following 56 mm rainstorm at SAFE of 30th June led to 2-14 cm deposition of fine mud at the core site – how lucky can you get, Sam?
- Numerous opportunities for replicate pits/cores located around the meander

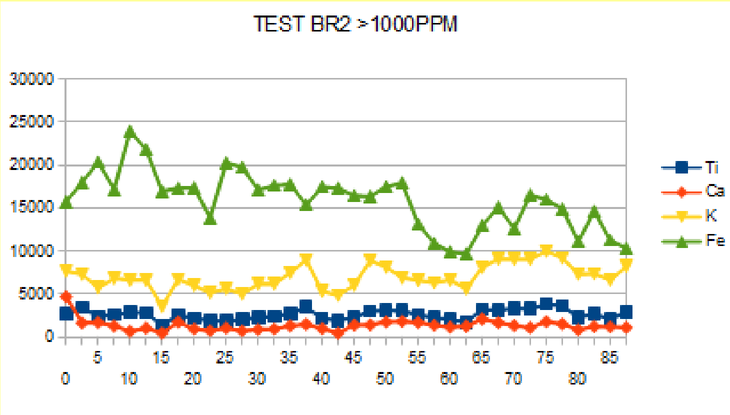


Repeat photographs of the actively shifting river bend location of Brantian NE sediment core site









Down-profile variations in elemental composition of the lateral bench core of the NE Brantian

- Note the substantial variations in Rb, Sr and Zn (TOP), Mn (MIDDLE) and Fe (BOTTOM)
- The working hypothesis is that these are linked to changes in source processes (especially increases in deep source material from landslides) during recent logging phases
- Data in the graphs are for composite samples; future work will focus on the fine <63µ fraction - which is the suspended sediment fraction
- The core will also be dated using Pb-210 and Cs-137 isotope analysis


180
210 220 230


10 20 30
60

4. Channel responses to land-use change

Project monitoring of channel cross-section change in the project catchments + undergraduate dissertation project of Emily Perryman (fieldwork July 2014)

Channel change

Progress:

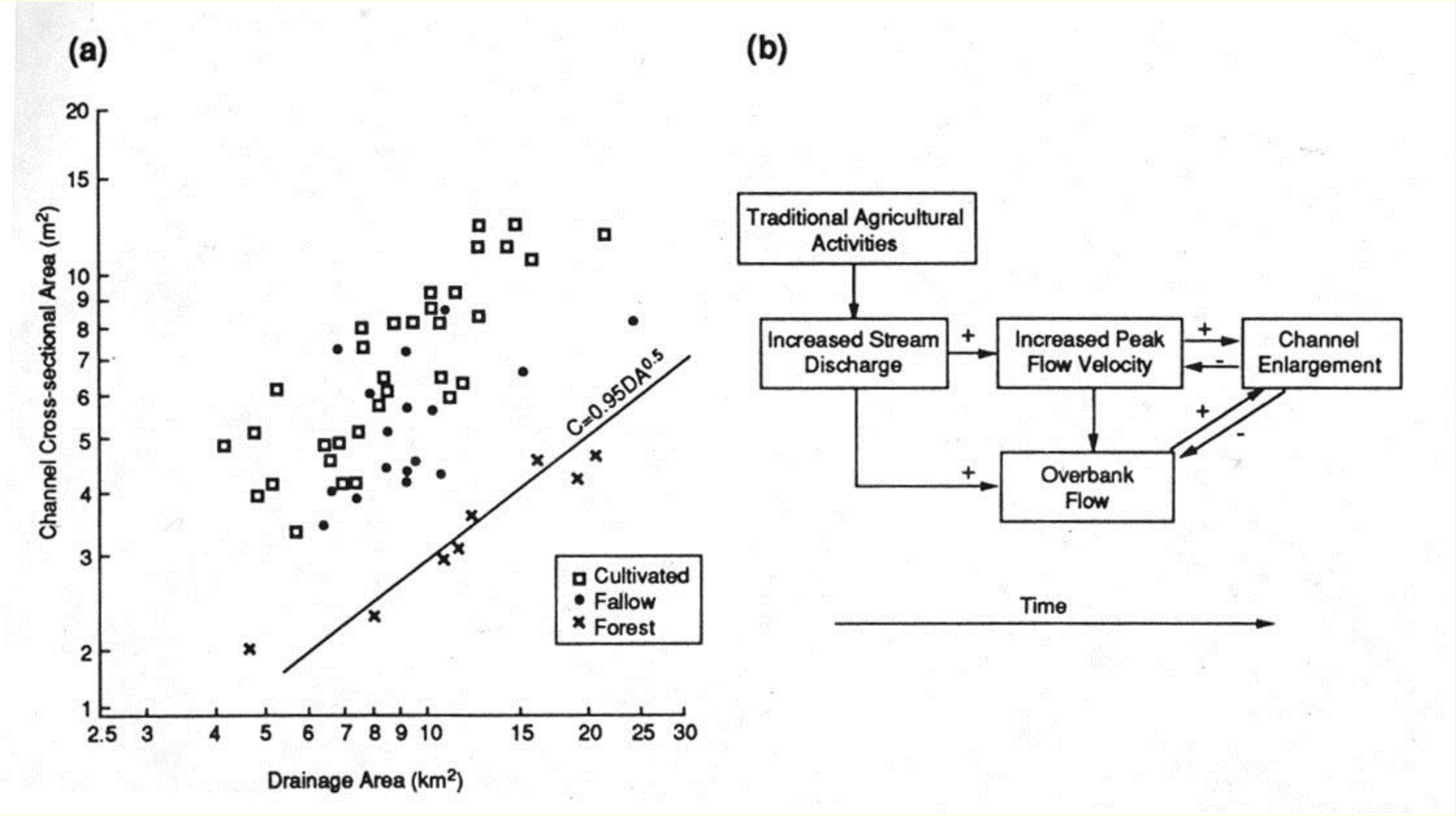
1) Around 10 repeat-measurement channel cross-sections have been established at 100-metre intervals along the main stream of each Project catchment to assess variations in channel response with riparian forest width to the current logging/clearance/conversion sequence

2) Emily Perryman's project is exploring how bankfull cross-section size and shape vary with land-use. She is testing the hypotheses that size and width-depth ratio will vary in the following order:

Oil palm > recently logged forest > long post-logging forest > primary forest

3) Fieldwork carried out in the Danum area (primary and long-post-logging forest) and SAFE area (recently logged + oil palm) in July 2014 – analysis in progress

The only previous study of this kind was that of Odermerho (1984) who assessed channel size change through the shifting agriculture cycle in SW Nigeria



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+ Alice for some of the water samples

SAFE PROJECT RAINFALL (July 2011-June 2014)

OLD BASE CAMP

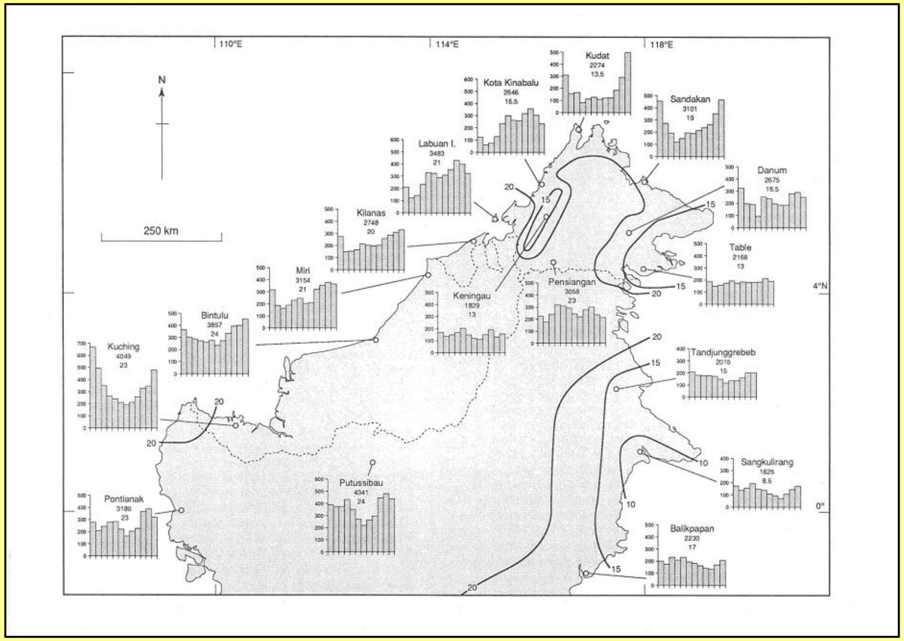
2011-12 annual rainfall 2731.4 mm
2012-13 annual rainfall 2569.4 mm
Highest month: 455.5 mm (April 2012)
Lowest month: 78.8 mm (July 2011)
Daily falls> 50 mm: 4 in 2011-12; 7 in 2012-13
Max.daily fall: 76.8 mm on 1st March 2013

NEW BASE CAMP

2012-13 annual rainfall 2485.8 mm
Highest month: 359.0 mm (April 2014)
Lowest month: 66.0 mm (March 2014)
Daily falls> 50 mm: 8 in 2013-14
Max.daily fall: 90.0 mm 0n 16th April 2014

DANUM VALLEY FIELD CENTRE

2011-12 annual rainfall 3203.8 mm
2012-13 annual rainfall 3244.9 mm
2013-14 annual rainfall 2998.6 mm
Daily falls> 50 mm: 13 in 2011-12, 6 in 2012-13, 13 in 2013-14



Rainfall regimes (LEFT) and heavy daily rainfall characteristics of the stations in northern Borneo used in the study

Station	Mean annual rainfall (mm)	Mean annual frequency of daily rainfalls ≥50 mm	≥100 mm	≥200 mm	Highest recorded daily rainfall (mm)	
Sandakan	3132.3	15.95	3.09	0.24	464.6	27 Dec 1973
Kota Kinabalu	2664.1	12.99	2.02	0.17	295.7	29 Aug 1917
Tawau	1862.2	5.52	0.45	0.00	190.0	9 July 2007
Danum	2882.9	9.36	0.88	0.00	182.2	9 Feb 2006
Kuching	4049.0	18.65	3.60	0.42	388.5	8 Feb 1876

Periods of record: Sandakan: 1906-12, 1915-40, 1952-3012; Kota Kinabalu: 1908-12, 1915-40, 1947-2012; Tawau: 1908-12, 1915-40, 1951-2012; Danum: 1985-2012; Kuching: 1876-88; 1900-26; 1960-2012.