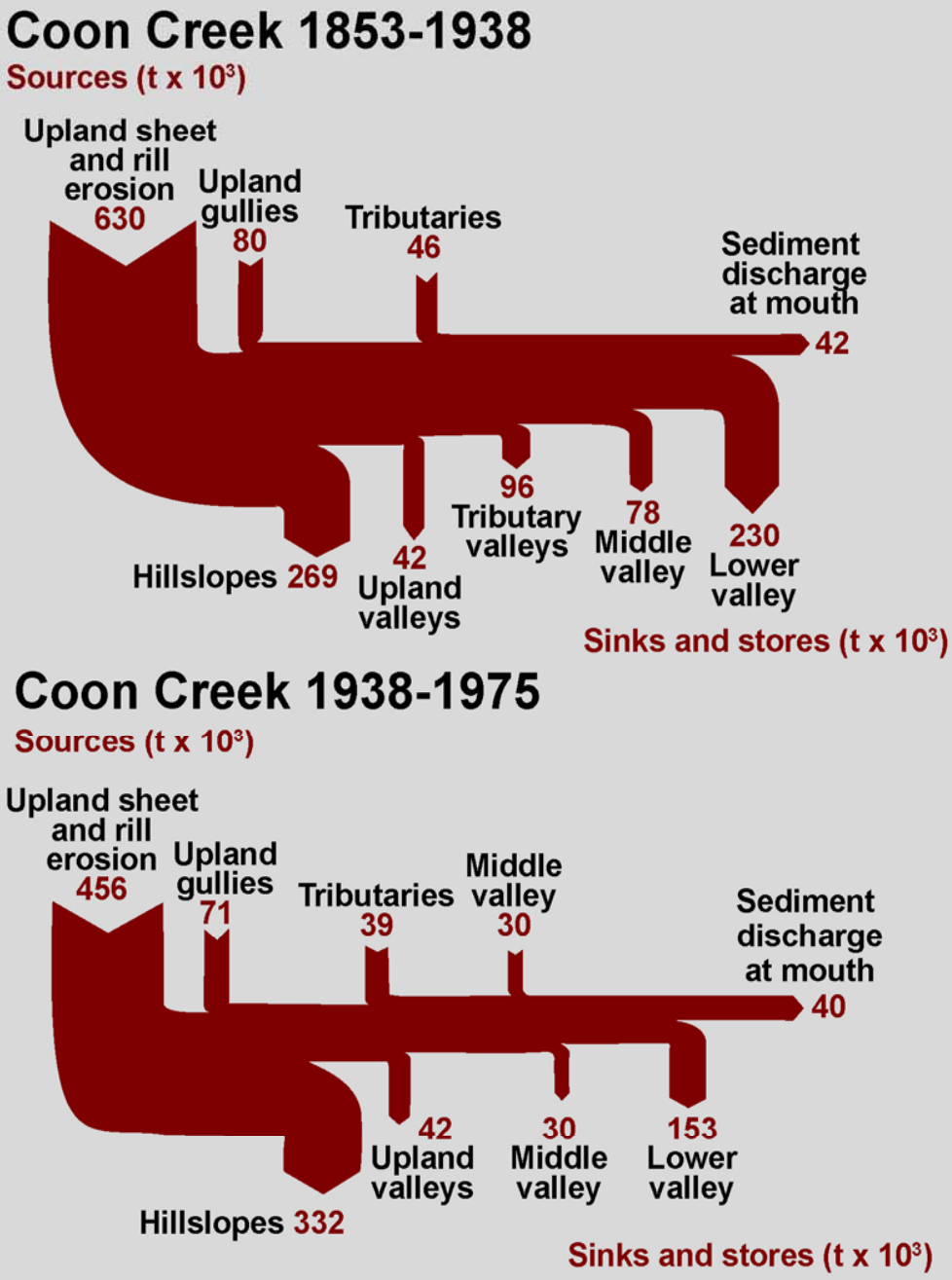
UNDERSTANDING AND QUANTIFYING SEDIMENT BUDGETS

DES WALLING
DEPARTMENT OF GEOGRAPHY

Regional Workshop on Discharge and Sediment Monitoring and Geomorphological Tools for the Lower Mekong Basin, October 21-22, 2008.

THE SEDIMENT BUDGET

(After Trimble)



THE SEDIMENT BUDGET

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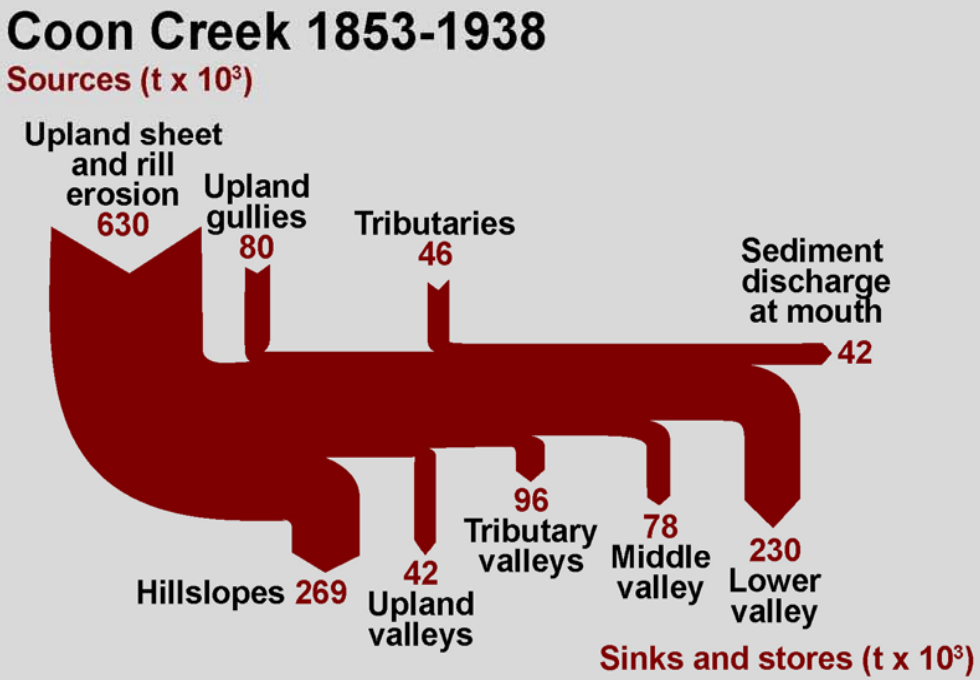
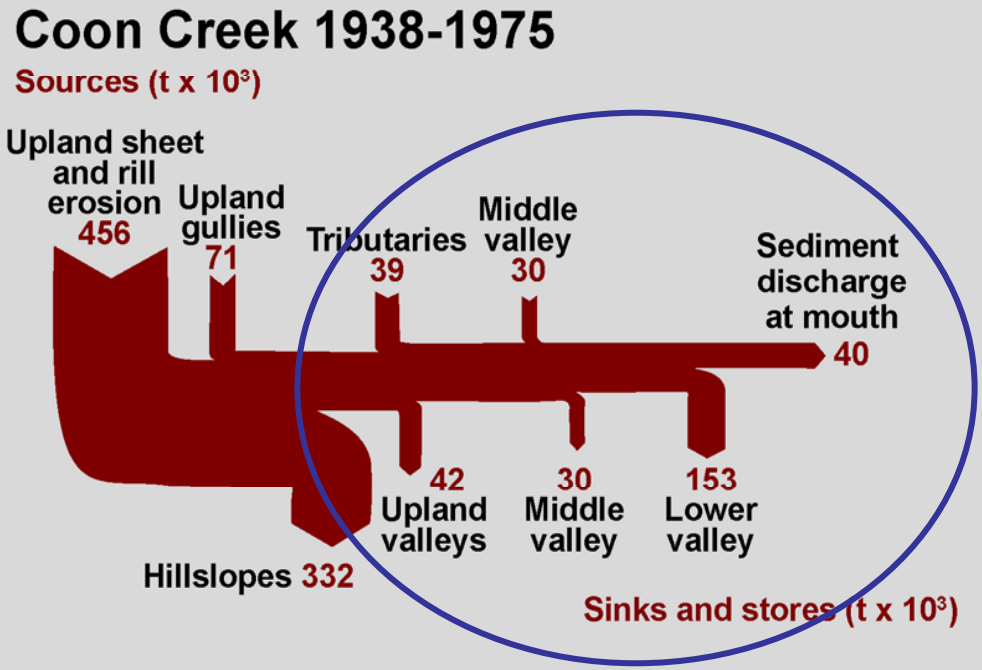
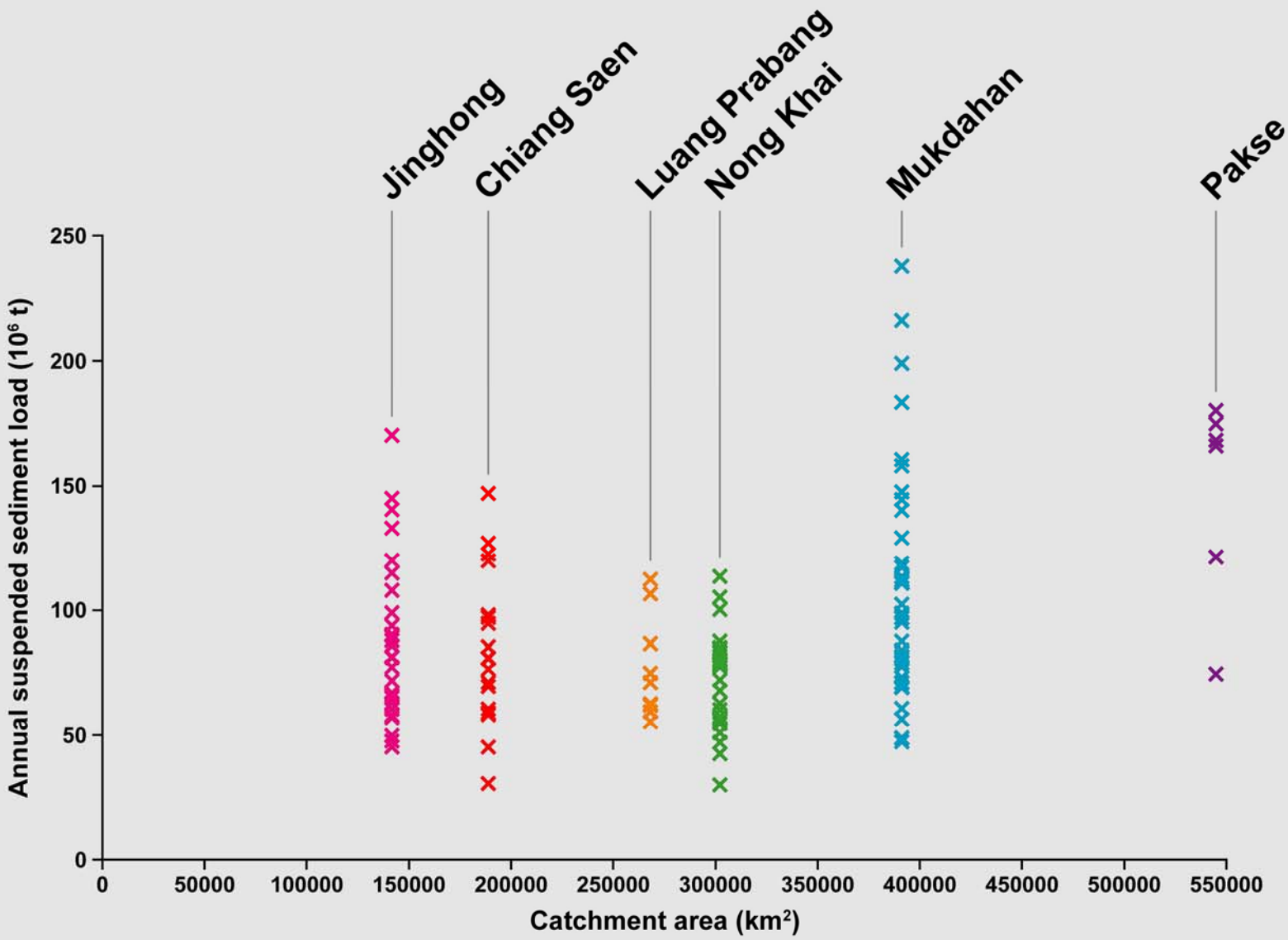
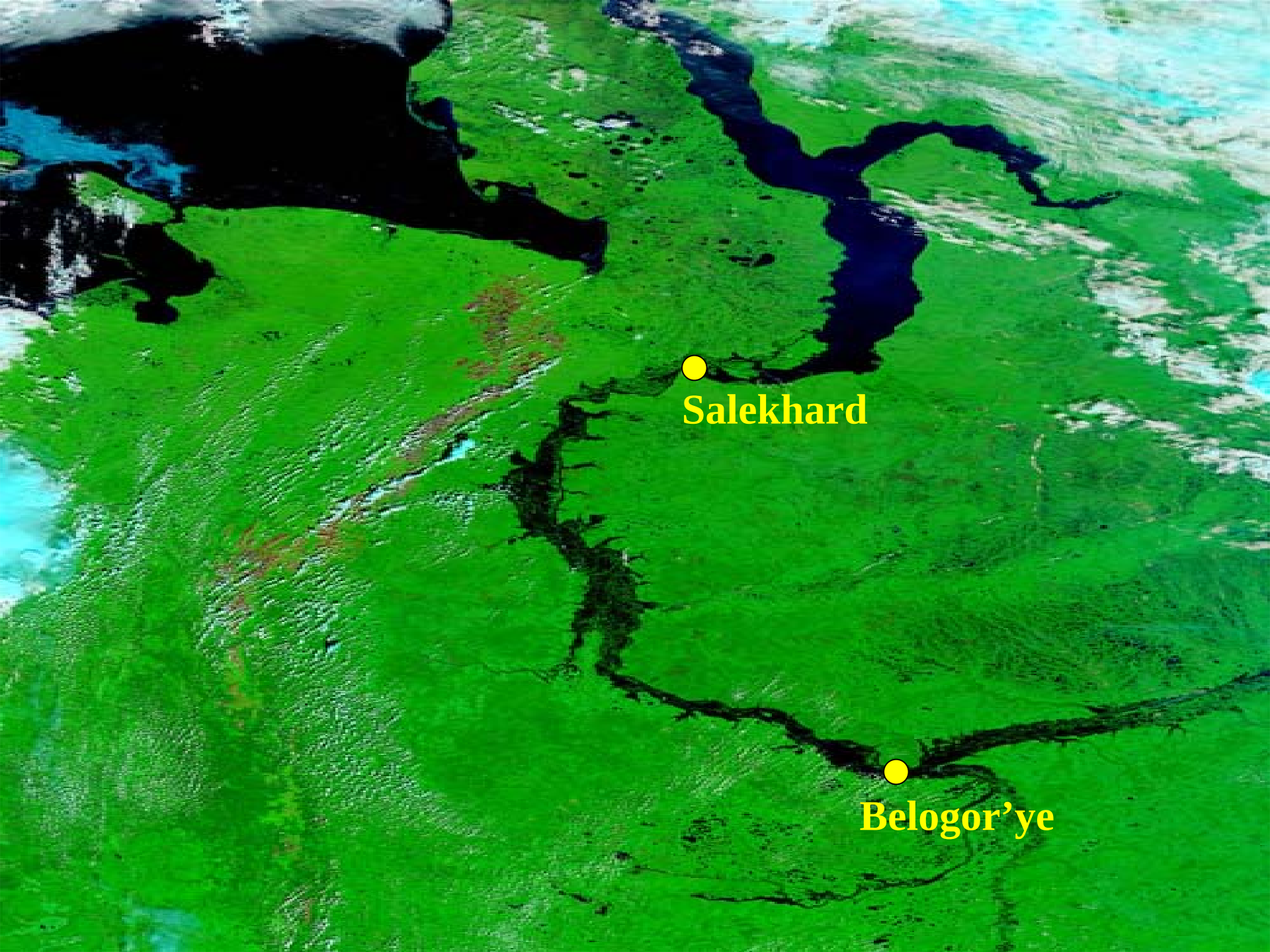





Jinghong
Chiang Saen
Luang Prabang
Nong Khai
Mukdahan
Pakse
Annual suspended sediment load (10⁶ t)
0
50
100
150
200
250
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
550000
Catchment area (km²)

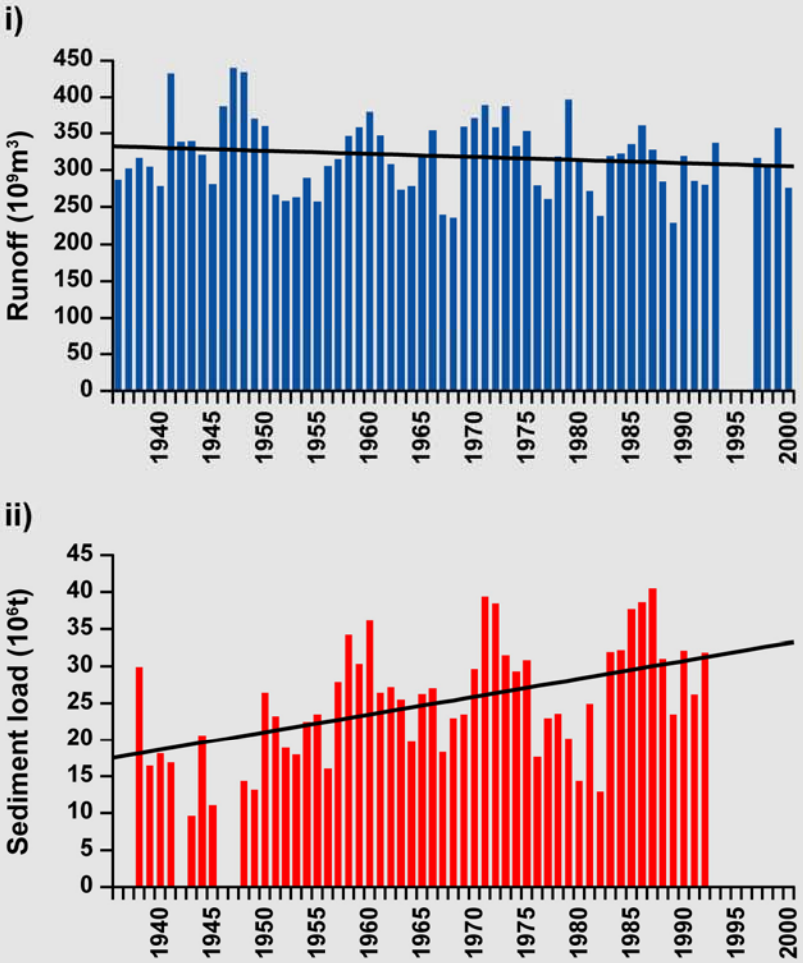

19 12 92

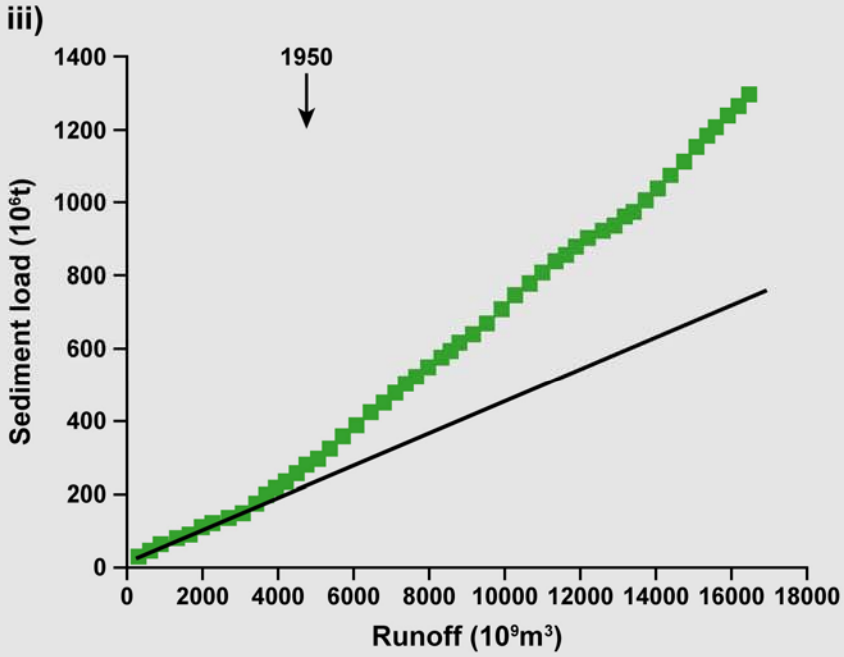

Salekhard
Belogor’ye

	Q ($km^3\ a^{-1}$)	Load ($10^6 t\ a^{-1}$)
Belogor'ye	322	28.4
Salekhard	396	16.2
% Change	+25%	-40%

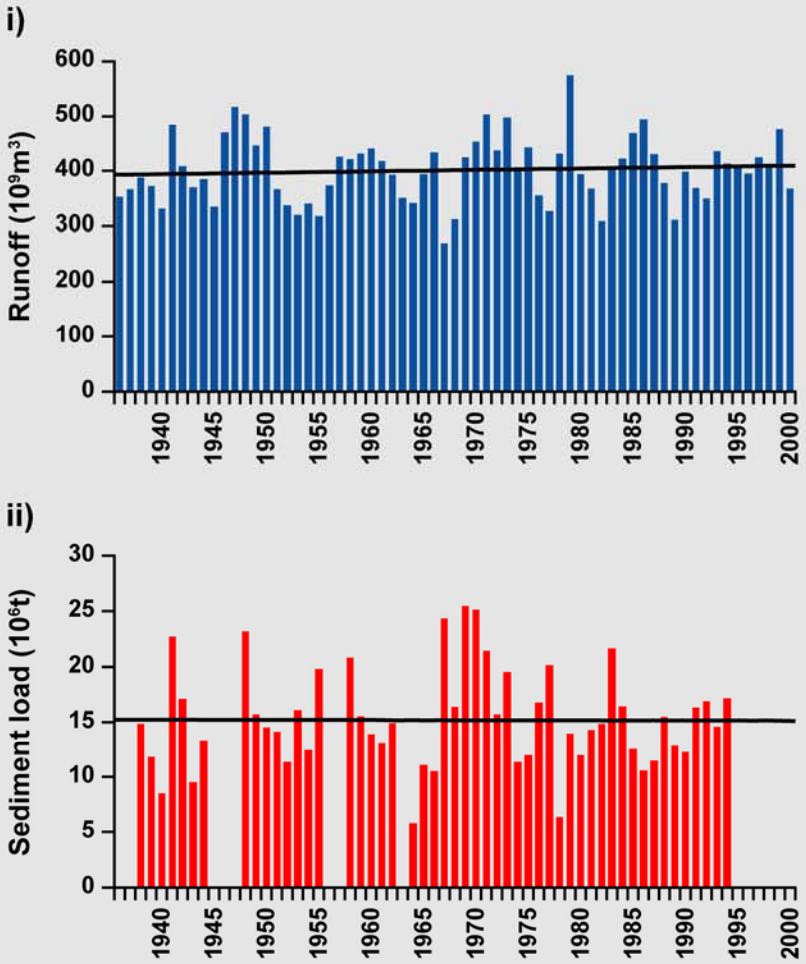
Based on Bobrovitskaya *et al.* (1996)

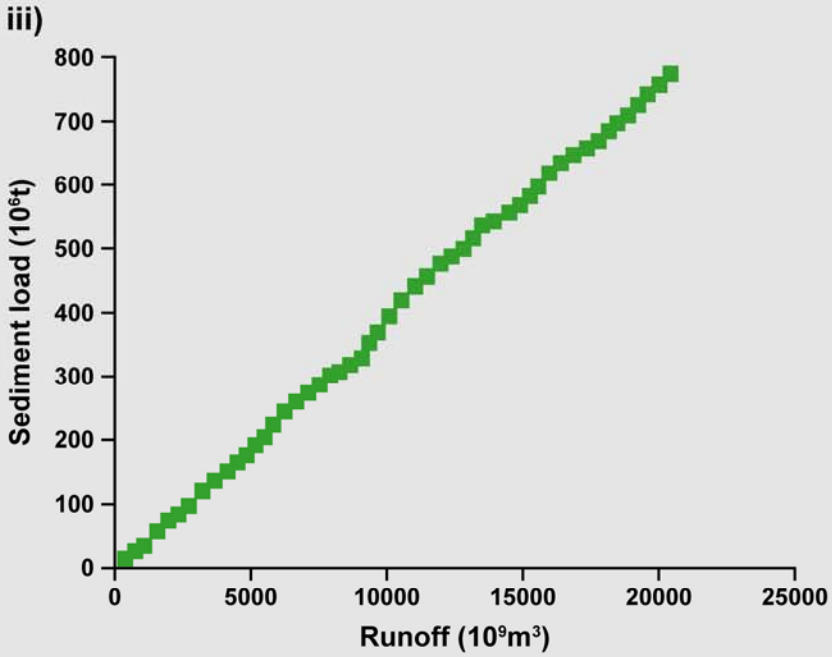
Ob River at Belegor'ye, Russia, 1936 - 2000





Ob River at Salekhard, Russia, 1936 - 2000





DOCUMENTING OVERBANK SEDIMENTATION RATES

(a) Indirect
(b) Direct

	Q ($km^3\ a^{-1}$)	Load ($10^6 t\ a^{-1}$)
Belogor'ye	**322**	**28.4**
Salekhard	**396**	**16.2**
% Change	**+25%**	**-40%**

Average Deposition Rate = 8 mm $year^{-1}$

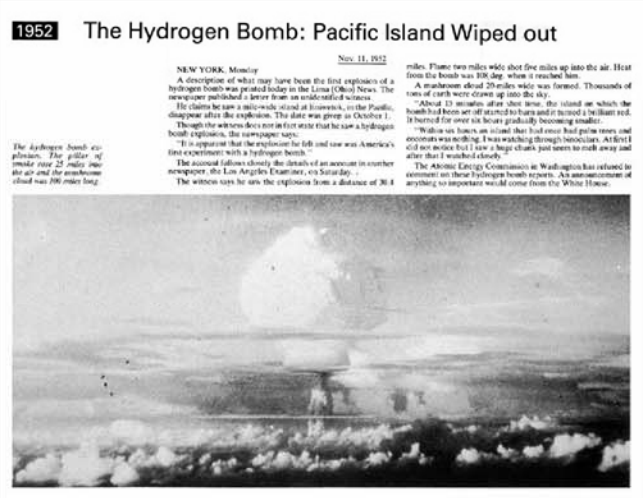
Direct Methods

(a) Traps or mats
(b) Fallout radionuclides

Using Fallout Radionuclides for Estimating Overbank Sedimentation Rates and Dating Recent Sediments

CAESIUM-137

HALF-LIFE: 30.2 years
ORIGIN: Weapons Testing



1952 The Hydrogen Bomb: Pacific Island Wiped out

Nov. 11, 1952

NEW YORK, Monday

A description of what may have been the first explosion of a hydrogen bomb was printed today in the Lima (Ohio) News. The newspaper published a letter from an unidentified witness.

He claims he saw a mile-wide island at Eniwetok, in the Pacific, disappear after the explosion. The date was given as October 1.

Though the witness does not in fact state that he saw a hydrogen bomb explosion, the newspaper says:

"It is apparent that the explosion he felt and saw was America's first experiment with a hydrogen bomb."

The account follows closely the details of an account in another newspaper, the Los Angeles Examiner, on Saturday. .

The witness says he saw the explosion from a distance of 30 miles. Flame two miles wide shot five miles up into the air. Heat from the bomb was 810 deg. when it reached him.

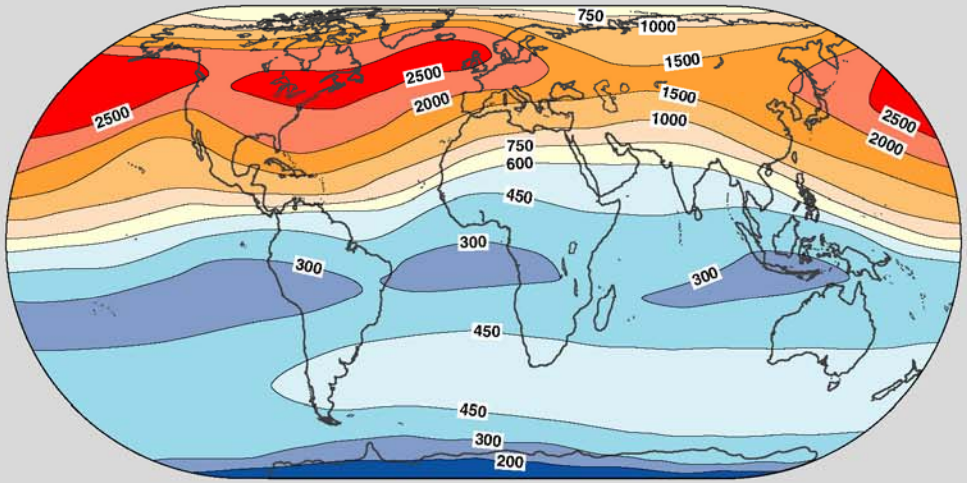
A mushroom cloud 20 miles wide was formed. Thousands of tons of earth were drawn up into the sky.

"About 15 minutes after shot time, the island on which the bomb had been set off started to burn and it turned a brilliant red. It burned for over six hours gradually becoming smaller.

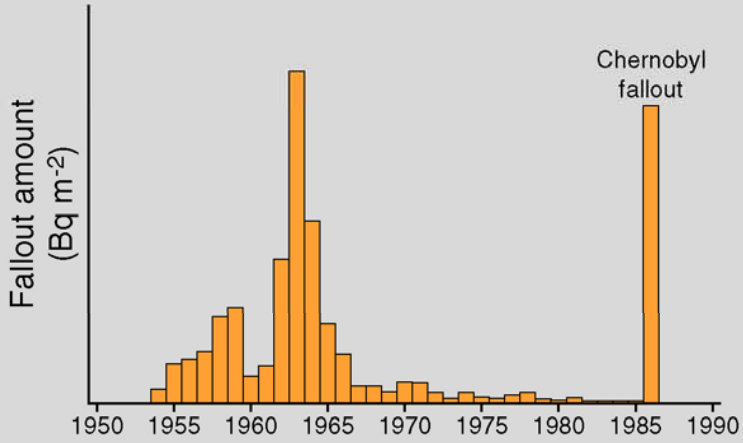
"Within six hours an island that had once had palm trees and coconuts was nothing. I was watching through binoculars. At first I did not notice but I saw a huge chunk just seem to melt away and after that I watched closely.

The Atomic Energy Commission at Washington has refused to comment on these hydrogen bomb reports. An announcement of anything so important would come from the White House.

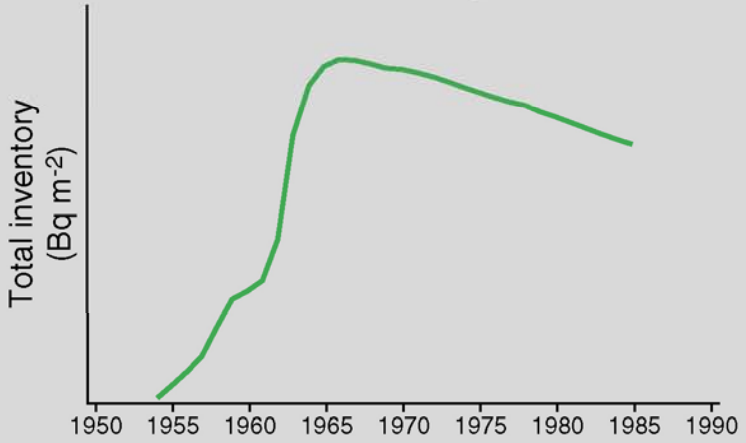
The hydrogen bomb explosion. The pillar of smoke rose 25 miles into the air and the mushroom cloud was 100 miles long.



Fallout Record

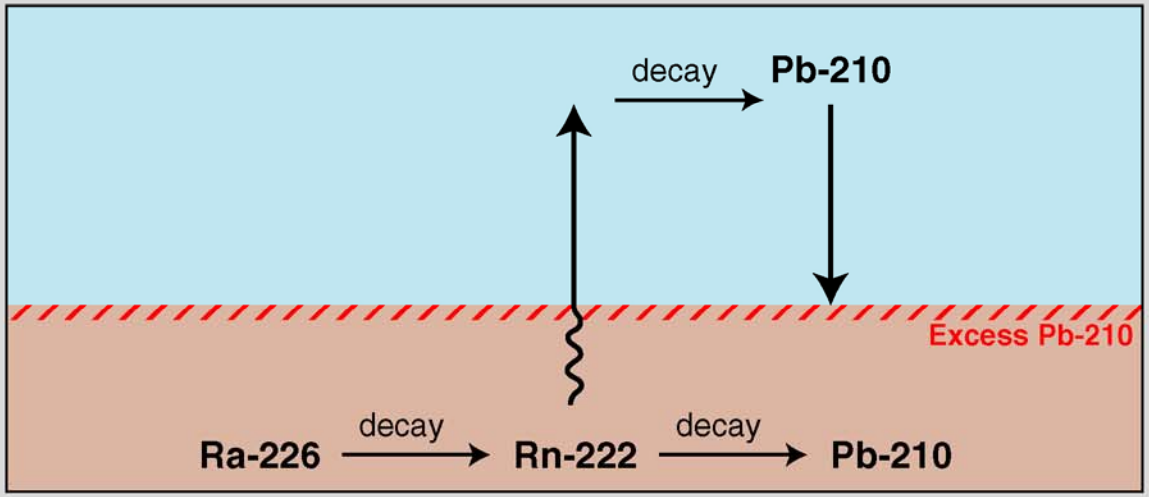


Cumulative Inventory

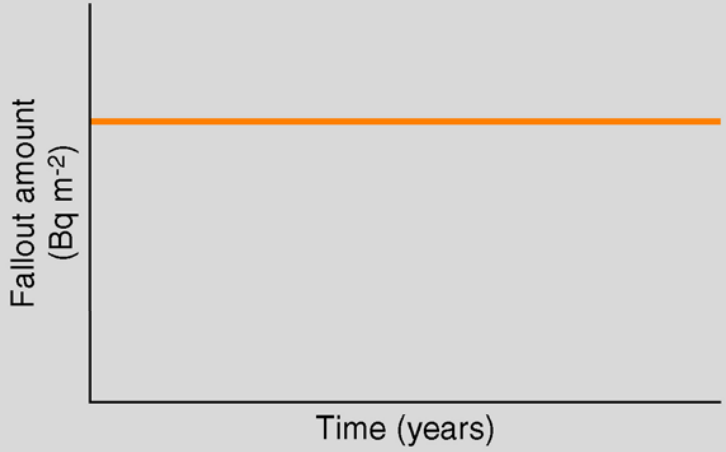


EXCESS LEAD-210

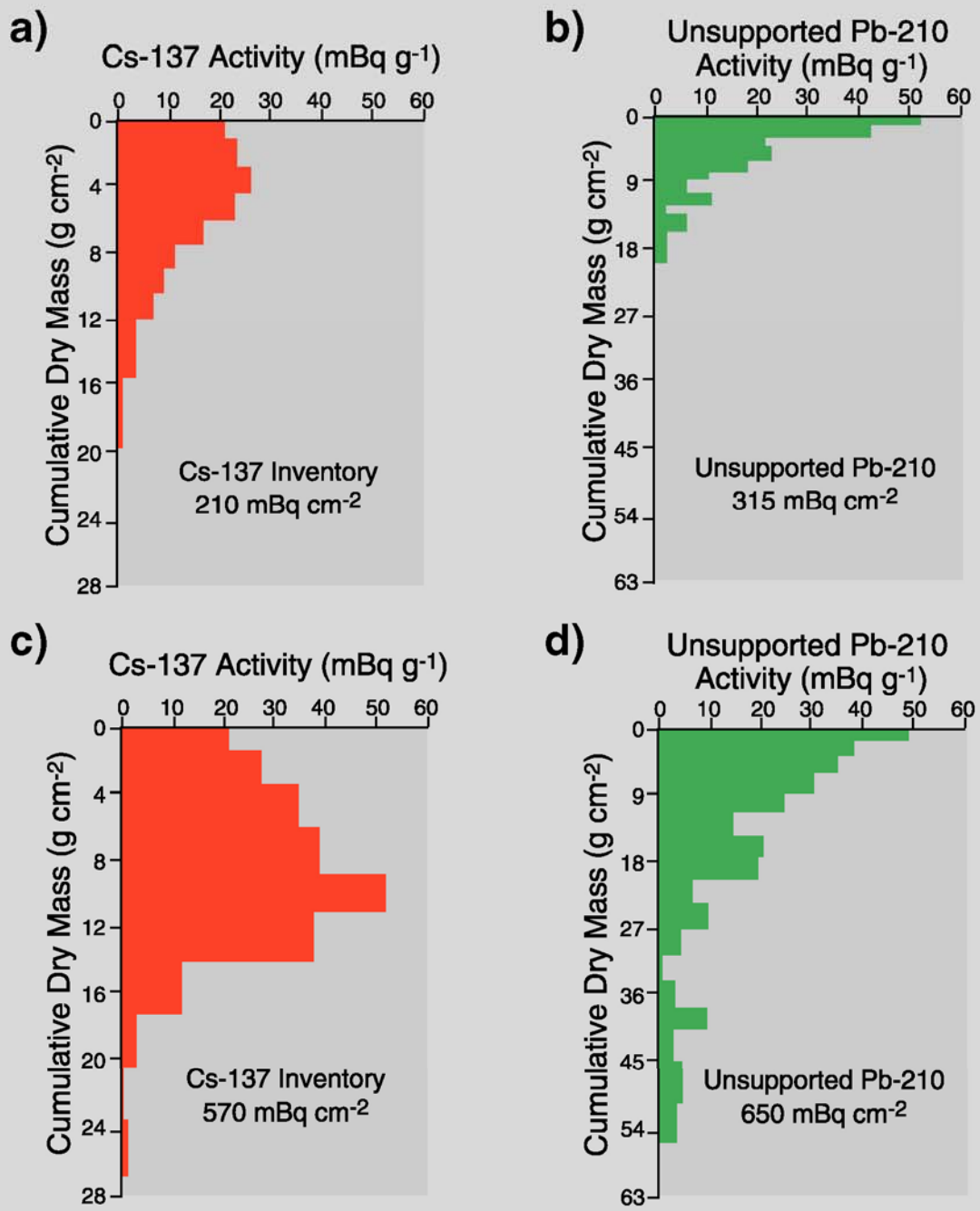
HALF-LIFE: 22.3 years
ORIGIN: Natural Geogenic



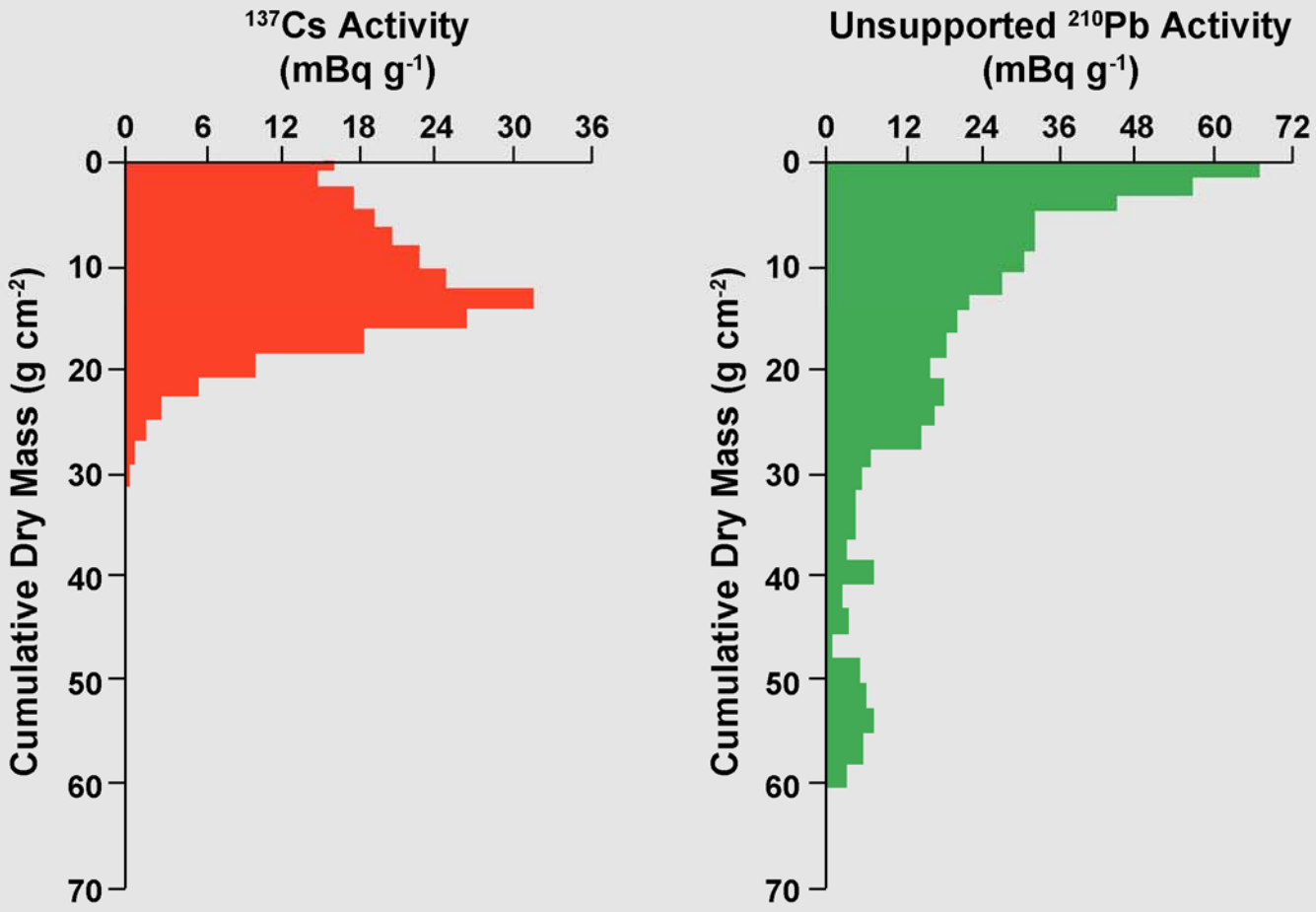
Fallout Record



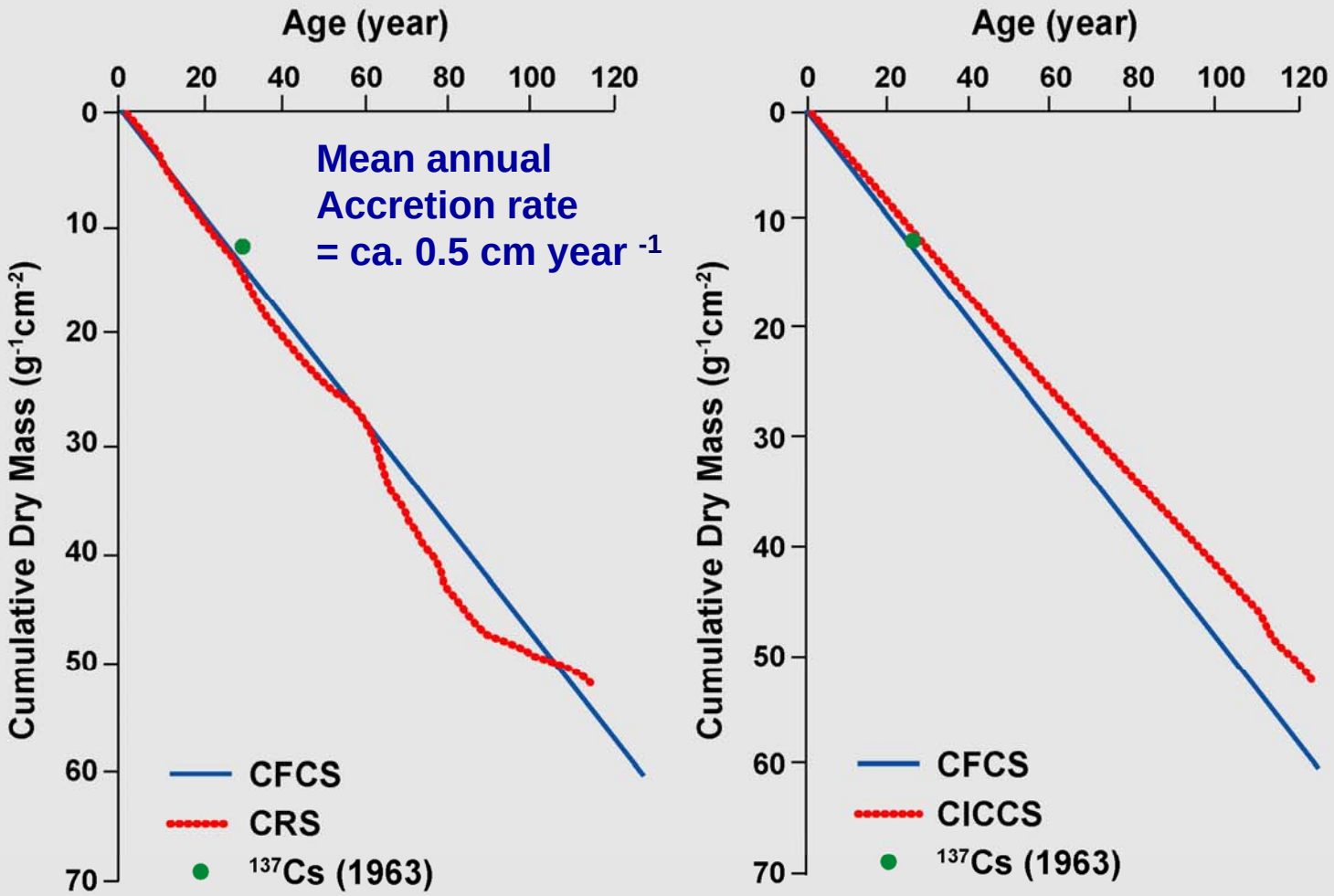
Cumulative Inventory


a)
Cs-137 Activity (mBq g-1)
0 10 20 30 40 50 60
0 4 8 12 16 20 24 28
Cumulative Dry Mass (g cm-2)
Cs-137 Inventory
210 mBq cm-2
b)
Unsupported Pb-210
Activity (mBq g-1)
0 10 20 30 40 50 60
0 9 18 27 36 45 54 63
Cumulative Dry Mass (g cm-2)
Unsupported Pb-210
315 mBq cm-2
c)
Cs-137 Activity (mBq g-1)
0 10 20 30 40 50 60
0 4 8 12 16 20 24 28
Cumulative Dry Mass (g cm-2)
Cs-137 Inventory
570 mBq cm-2
d)
Unsupported Pb-210
Activity (mBq g-1)
0 10 20 30 40 50 60
0 9 18 27 36 45 54 63
Cumulative Dry Mass (g cm-2)
Unsupported Pb-210
650 mBq cm-2

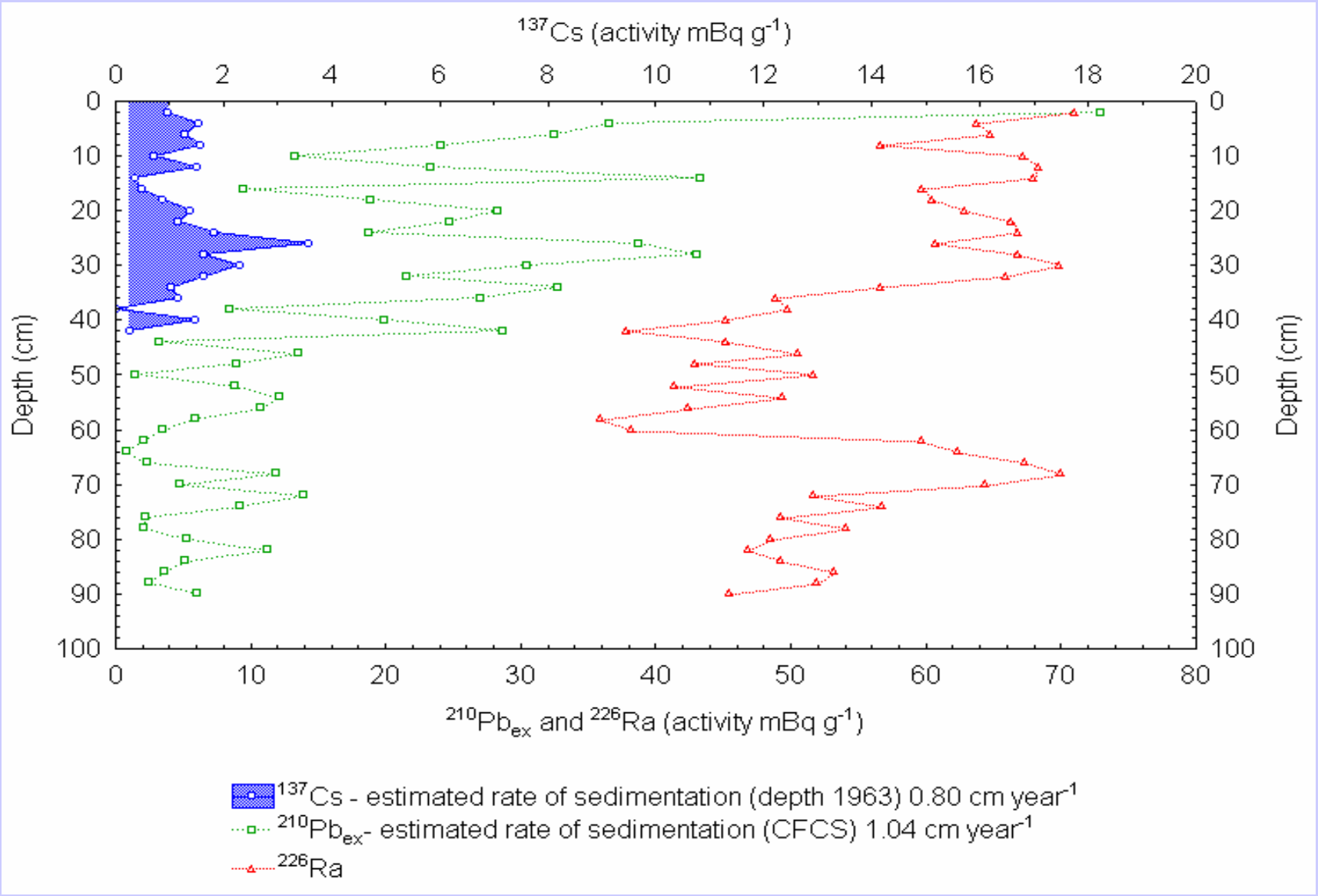
River Exe at Stoke Canon



River Exe at Stoke Canon



THE FLOODPLAIN OF THE TISTA RIVER HIMALAYA FOOTHILLS



OVERBANK SEDIMENTATION RATES ESTIMATED USING FALLOUT RADIONUCLIDE MEASUREMENTS BY OTHER INVESTIGATIONS

River	Country	Rate (cm year^{-1})	Author
UK Rivers	UK	0.04 - 1.42	Walling & He (1999)
Ironbark Creek	Australia	0.26 - 2.76	Ormerod (1998)
Maluna Creek	Australia	0.57	Cambell *et al.* (1982)
Carpathian rivers	Poland	0.7 - 5.0	Froehlich & Walling (1994)
Krishna & Cauvery	India	0.35 - 1.1	Vaithiyanathan *et al.* (1988)
Yamuna	India	2.2 - 6.1	Saxena *et al.* (2002)
Brahmaputra	Bangladesh	0.7 - 1.2	Allison *et al.* (1998)
Brahmaputra	Bangladesh	0.16	Goodbred & Kuehl (1998)
Hanalei	Hawaii	0.8 - 3.1	Calhoun & Fletcher (1999)
Wainimala	Fiji	3.2	Terry *et al.* (2002)

The Mekong ?

Spencer Wood et al. (in press)
Floodplain near Chiang Saen,
Ca. 5 m in 500 years = 1 cm year $^{-1}$

		cm year $^{-1}$
UK Rivers	UK	0.04 - 1.42
Ironbark Creek	Australia	0.26 - 2.76
Maluna Creek	Australia	0.57
Carpathian rivers	Poland	0.7 - 5.0
Krishna & Cauvery	India	0.35 - 1.1
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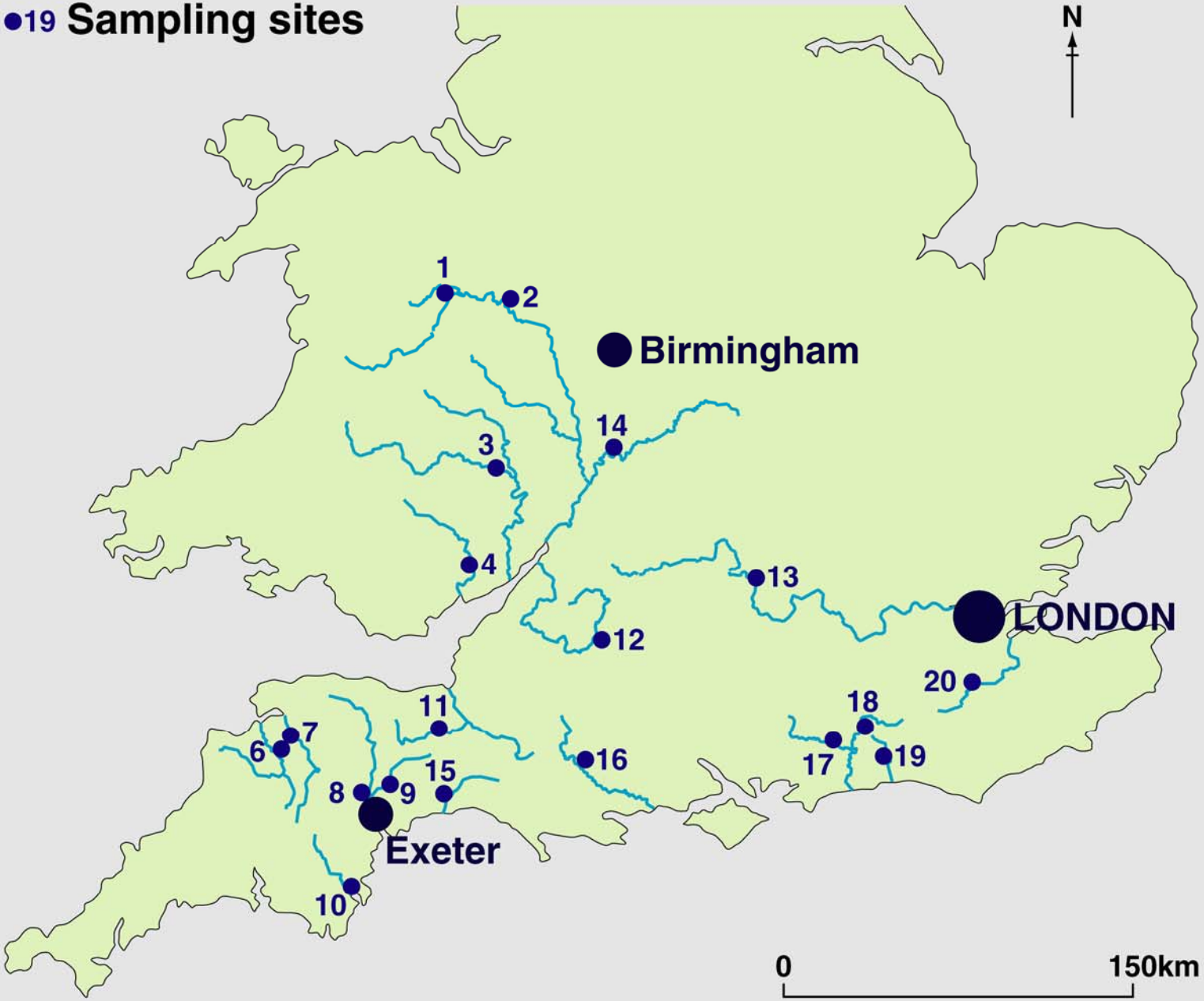
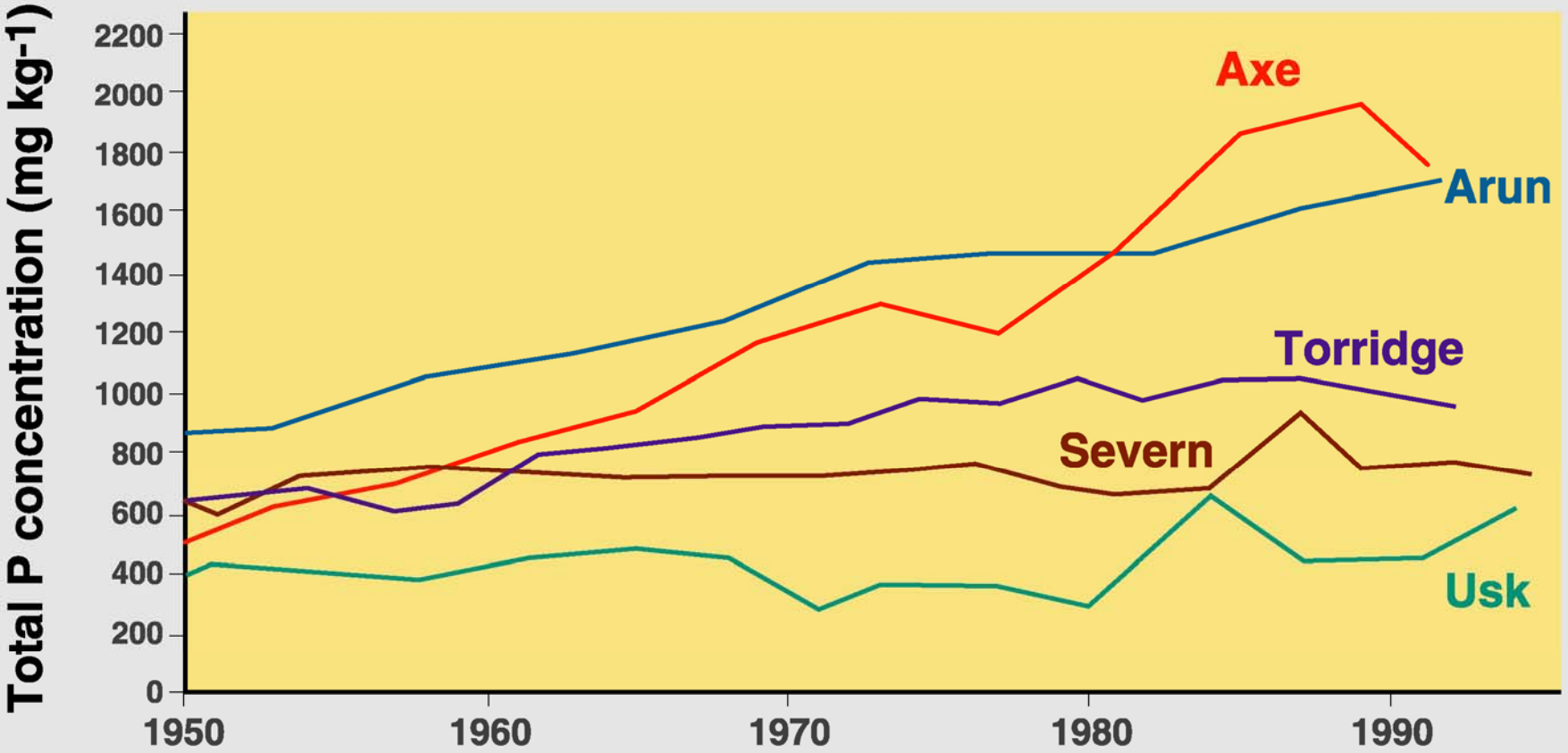
Hanalei	Hawaii	0.8 - 3.1
Wainimala	Fiji	3.2

FLOODPLAIN SEDIMENTS AS ARCHIVES


●19 Sampling sites
N
1
2
Birmingham
14
3
4
13
LONDON
12
20
18
11
7
6
16
17
19
15
8
9
Exeter
10
0
150km

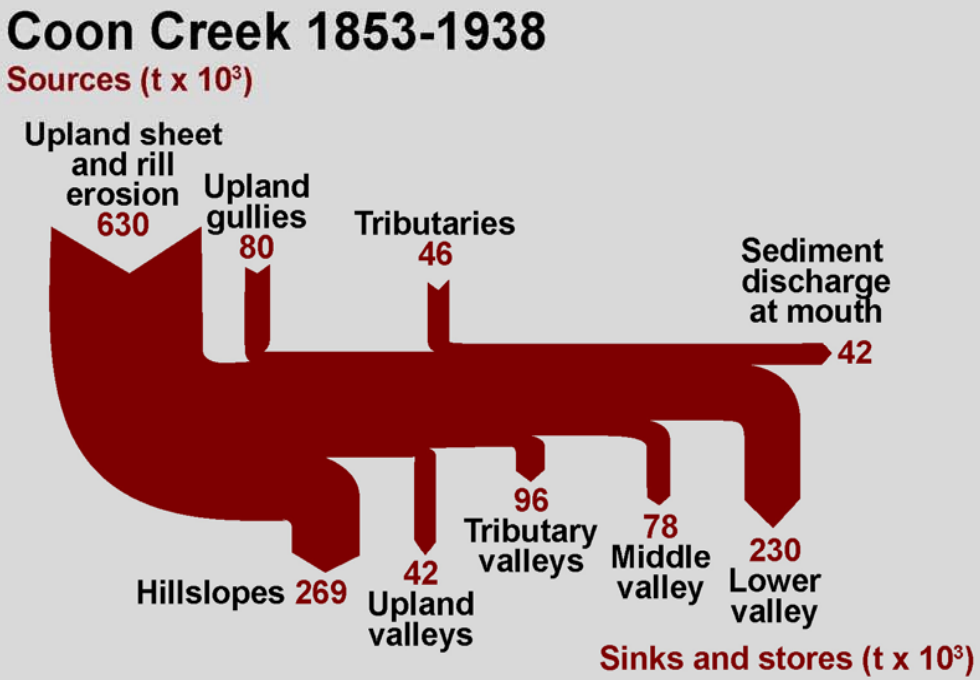

Total P concentration (mg kg-1)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1950
1960
1970
1980
1990
Axe
Arun
Torridge
Severn
Usk

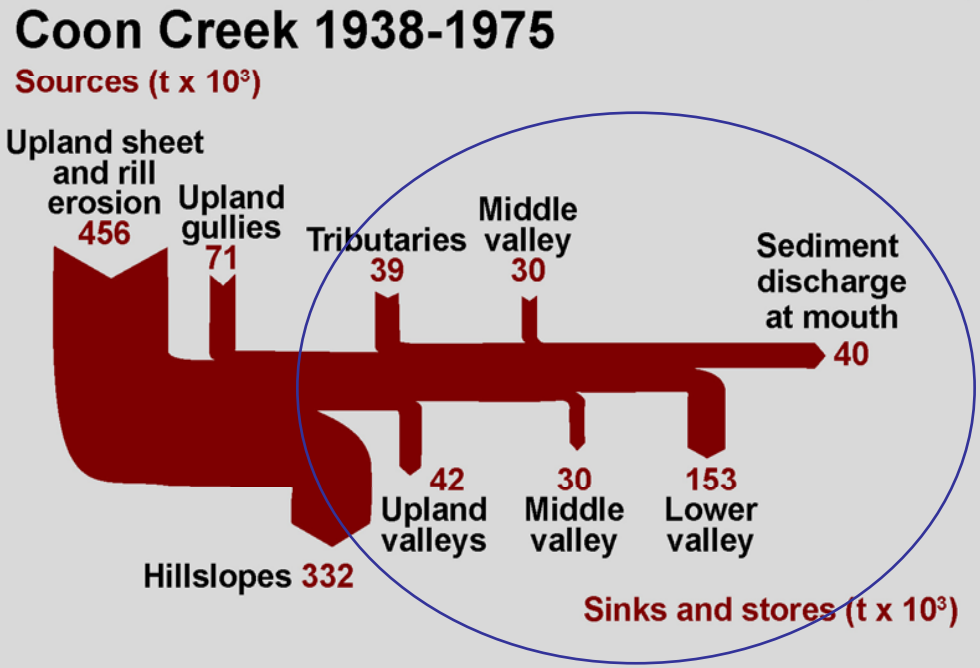
PHOSPHORUS STORAGE ON THE FLOODPLAINS OF BRITISH RIVERS

River and location	Increase in total-P content of deposited sediment 1950-1992 (%)
1 River Vyrnwy near Llanymynech	9
2 River Severn near Atcham	23
3 River Wye near Preston on Wye	17
4 River Usk near Usk	25
5 River Teme near Broadwas	45
6 River Torridge near Great Torrington	45
7 River Taw near Barnstaple	75
8 River Exe near Stoke Canon	65
9 River Culm near Silverton	33
10 River Start near Slapton	40
11 River Tone near Bradford on Tone	55
12 Bristol Avon near Langley Burrell	28
13 River Thames near Dorchester	30
14 Warwickshire Avon near Pershore	23
15 River Axe near Colyton	170
16 Dorset Stour near Shillingstone	53
17 River Rother near Fittleworth	33
18 River Arun near Billingshurst	94
19 River Adur near Partridge Green	147
20 River Medway near Penshurst	10

THE SEDIMENT BUDGET

(After Trimble)





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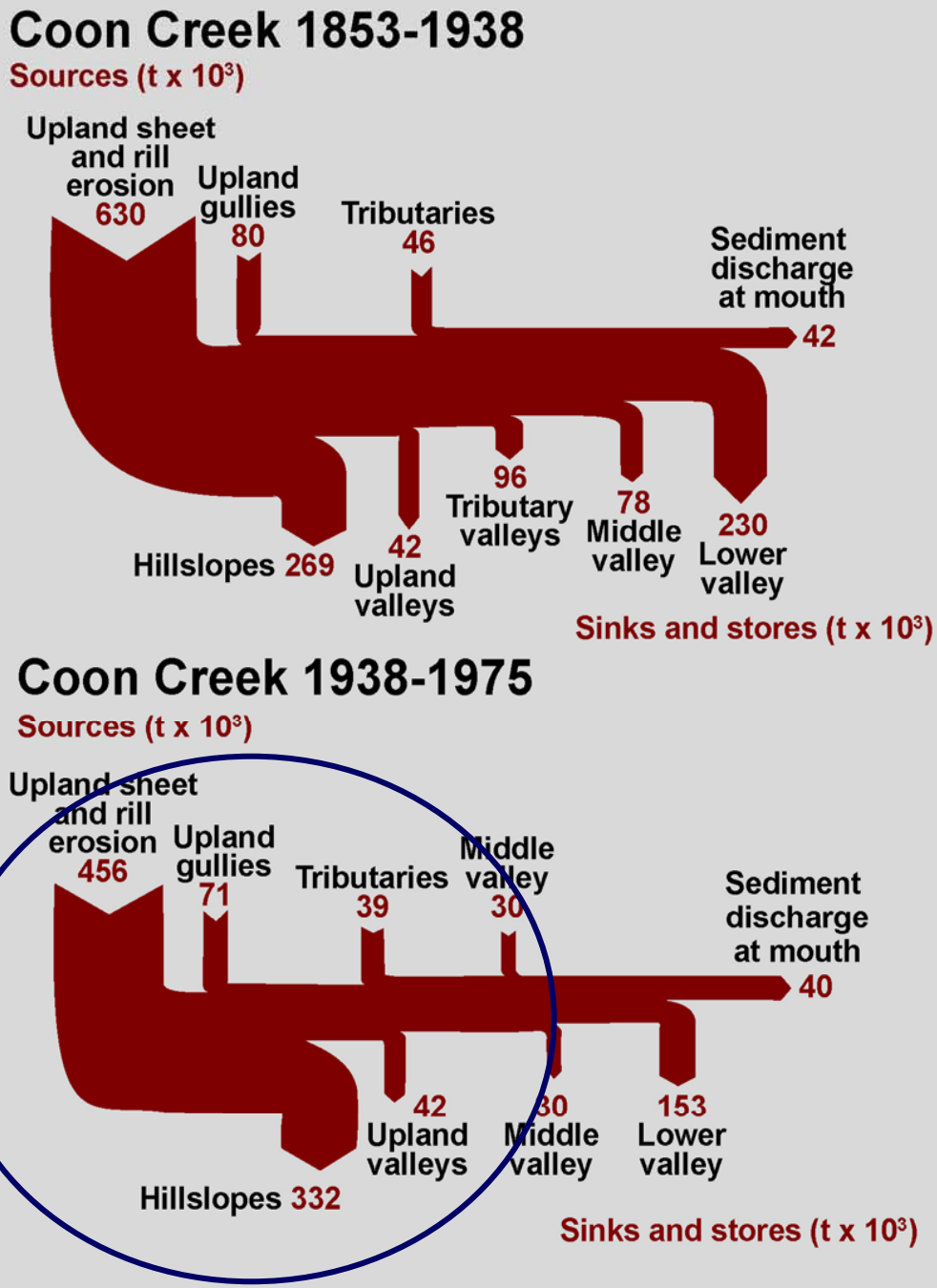
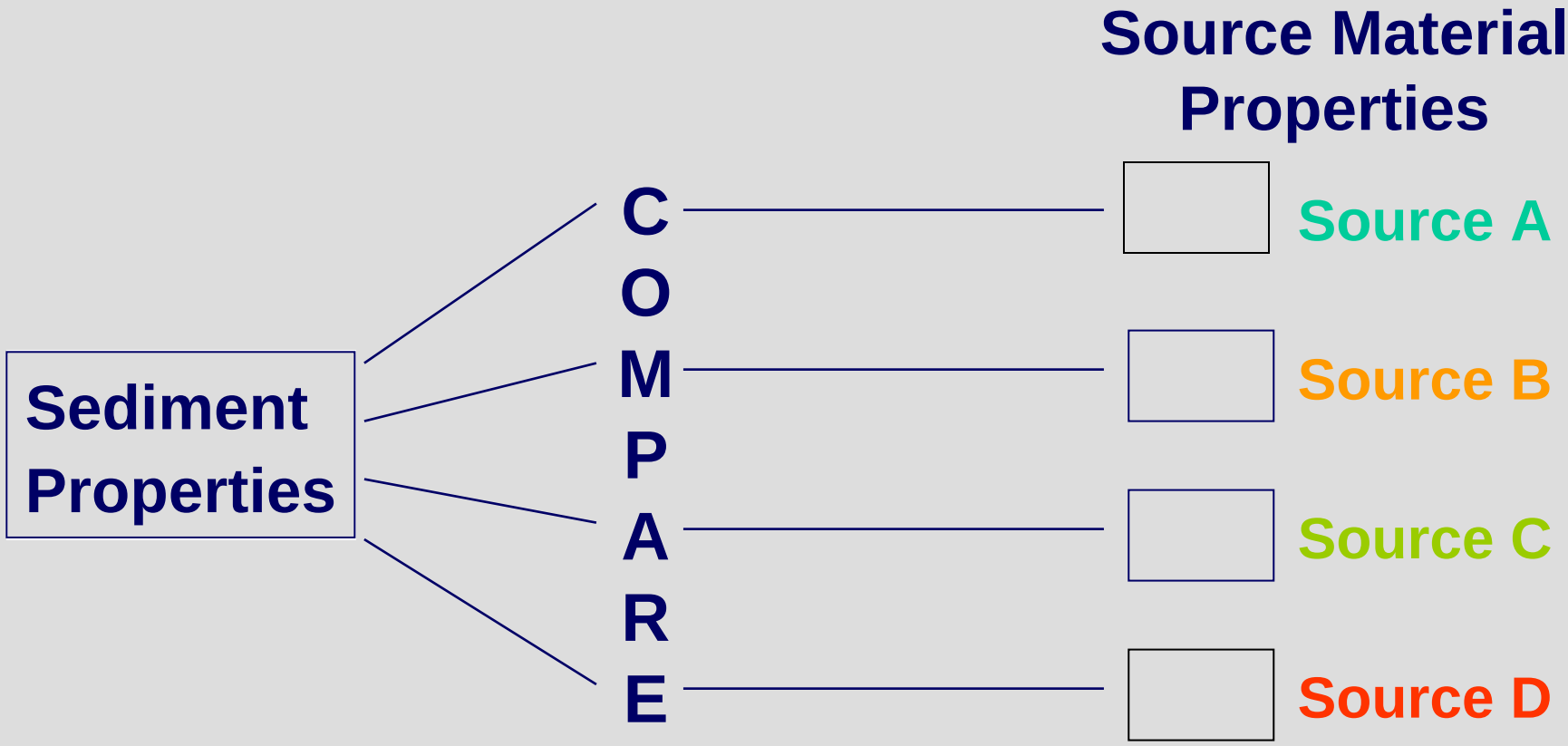
(After Trimble)



SEDIMENT SOURCE FINGERPRINTING



- Composite Fingerprints
- Multicomponent Mixing Model
- Particle size effects (Selectivity)

Fingerprint Properties

e.g. Geochemistry, mineral magnetics, radionuclides, isotopes

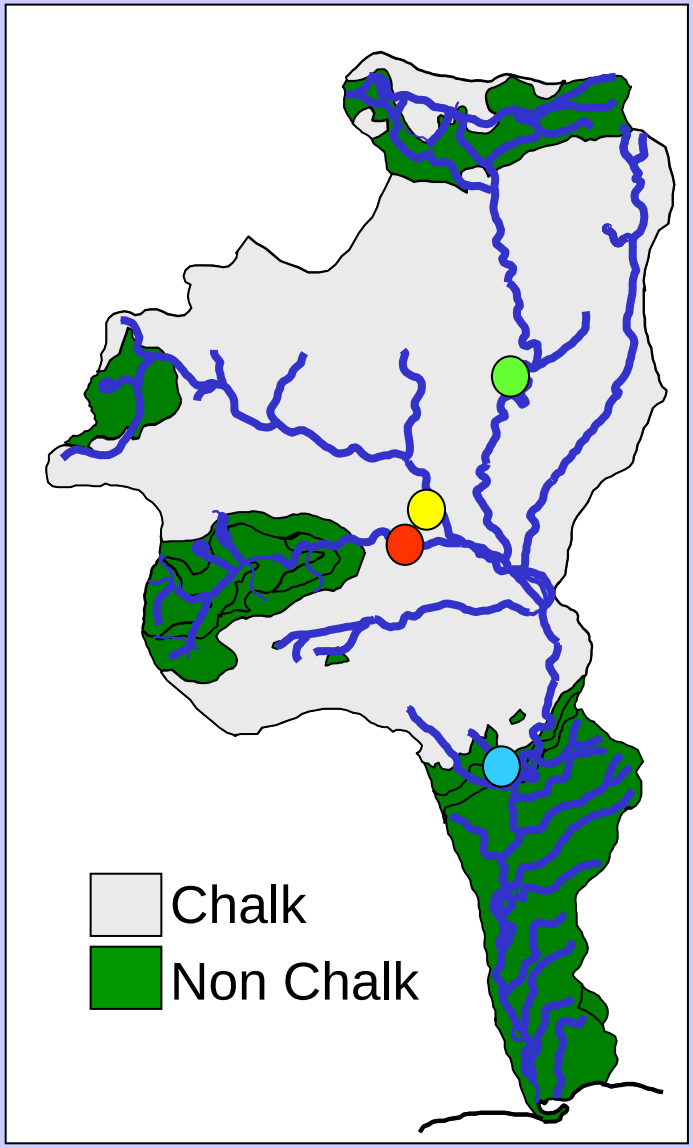
Source Discrimination

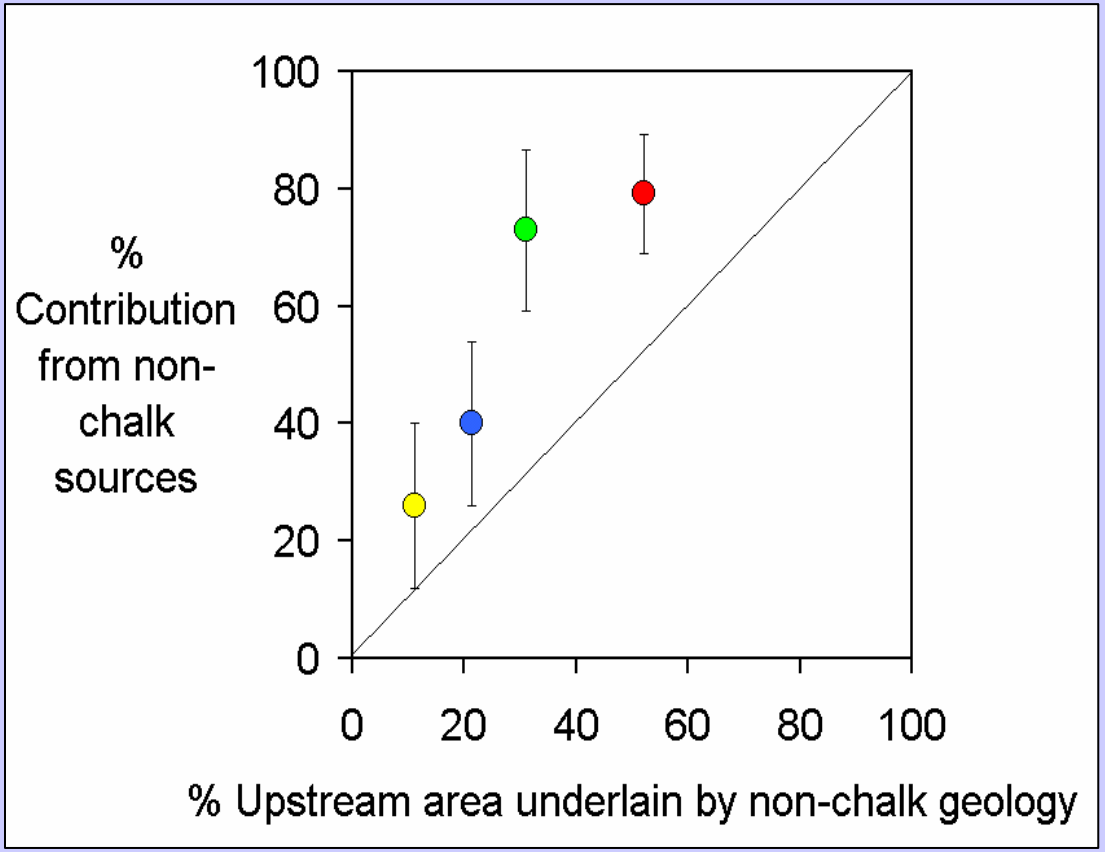
Statistical tests e.g. MDF

Source Apportionment

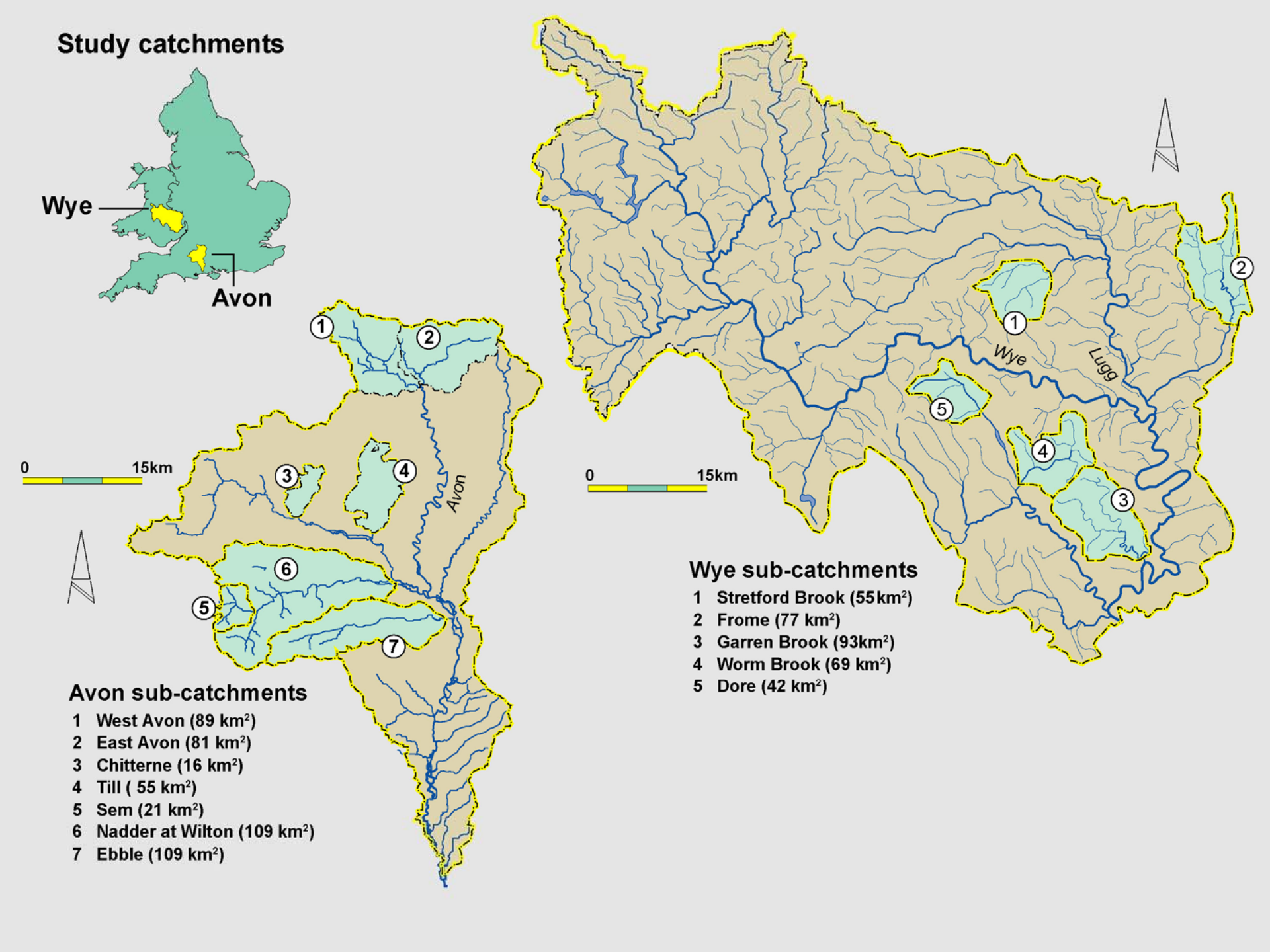
Mixing models, Uncertainty

The Provenance of Suspended Sediment in the Upper and Middle Hampshire Avon Catchment



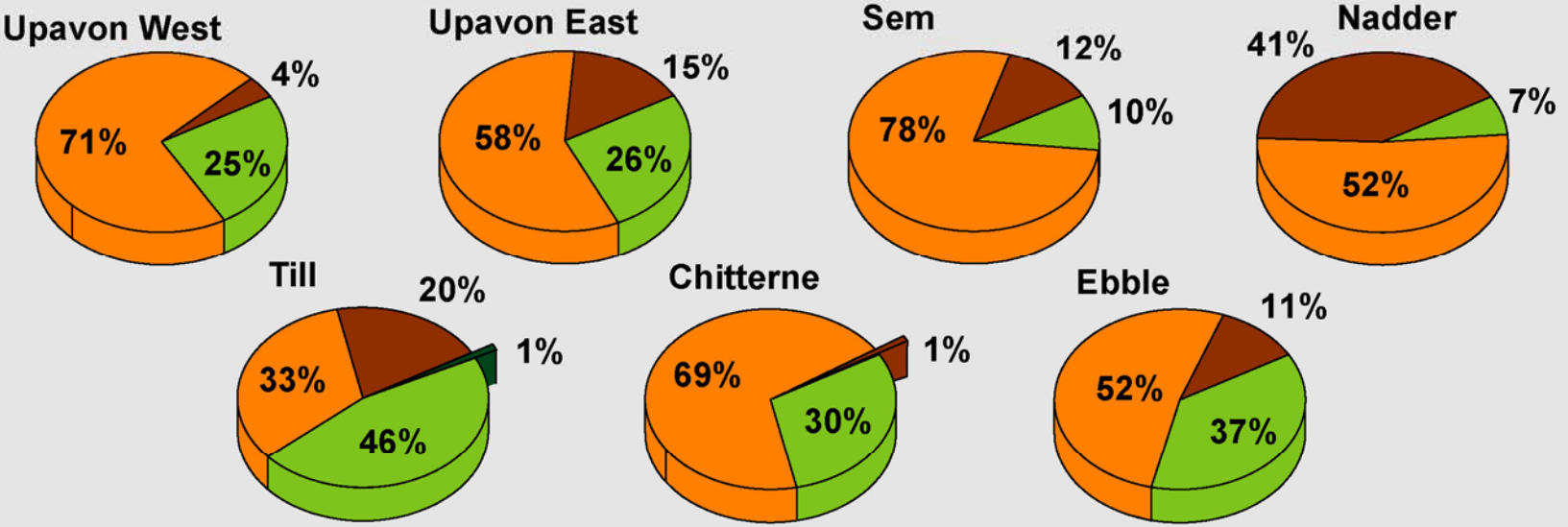


- R. Avon at Amesbury
- R. Wylye at South Newton
- R. Nadder at Wilton
- R. Avon at Fordingbridge

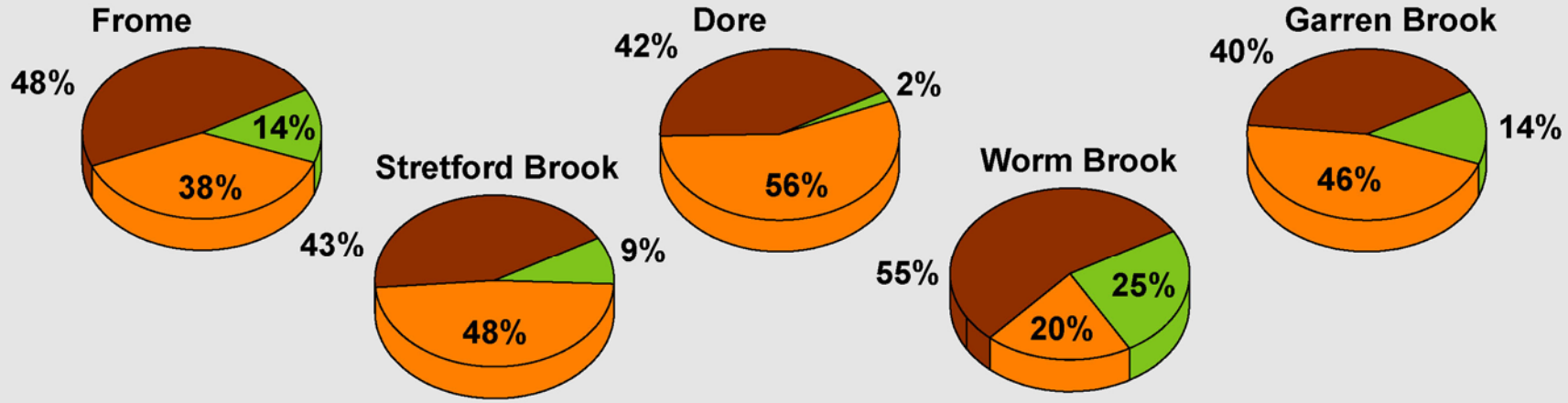

Study catchments
Wye
Avon
0
15km
Avon
1
2
3
4
5
6
7
Avon sub-catchments
1 West Avon (89 km²)
2 East Avon (81 km²)
3 Chitterne (16 km²)
4 Till (55 km²)
5 Sem (21 km²)
6 Nadder at Wilton (109 km²)
7 Ebble (109 km²)
0
15km
Wye
Lugg
1
2
3
4
5
Wye sub-catchments
1 Stretford Brook (55km²)
2 Frome (77 km²)
3 Garren Brook (93km²)
4 Worm Brook (69 km²)
5 Dore (42 km²)

SUSPENDED SEDIMENT SOURCES

Avon sub-catchments



Wye sub-catchments



Channel banks / subsurface sources

Cultivation

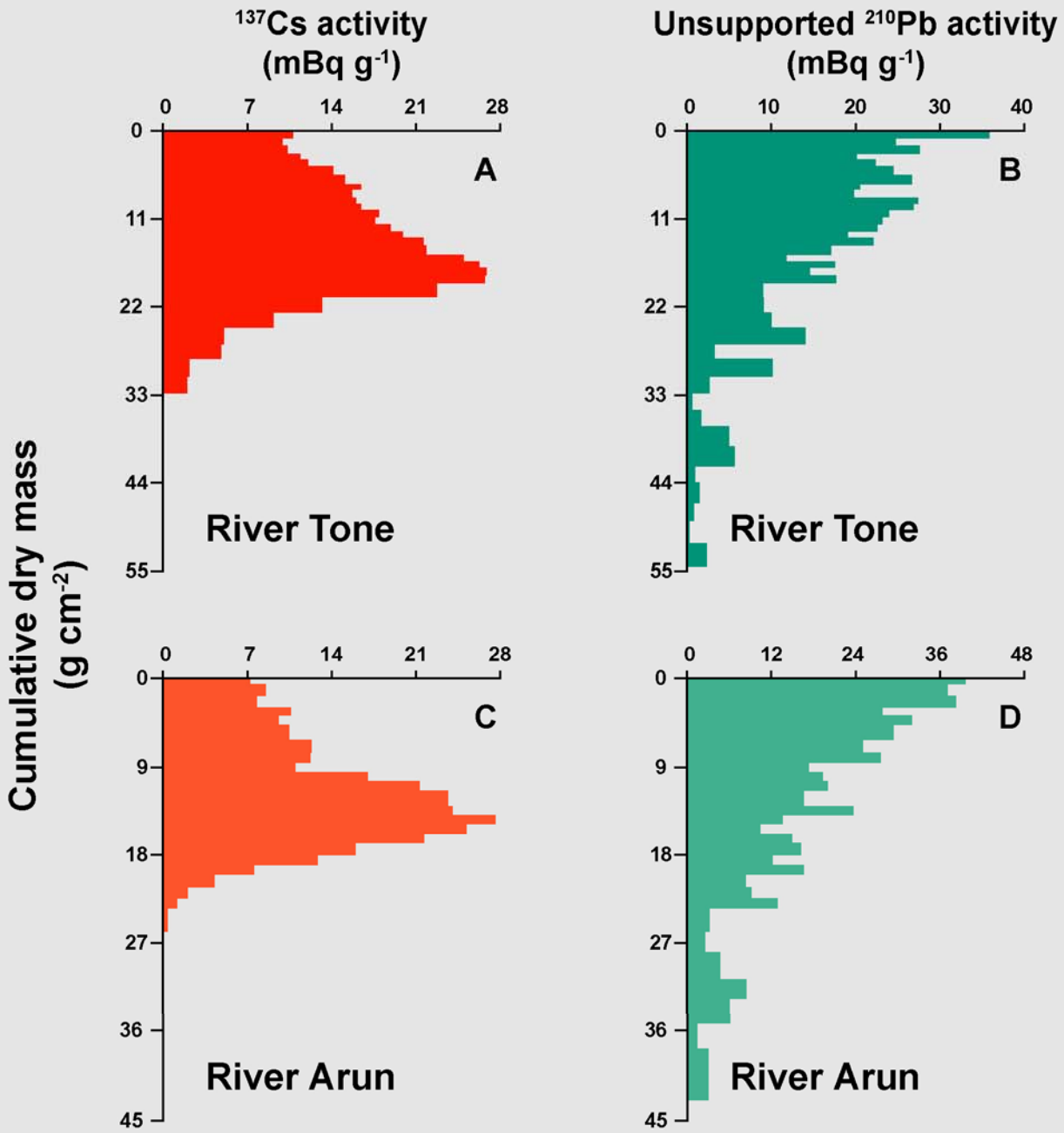
Pasture

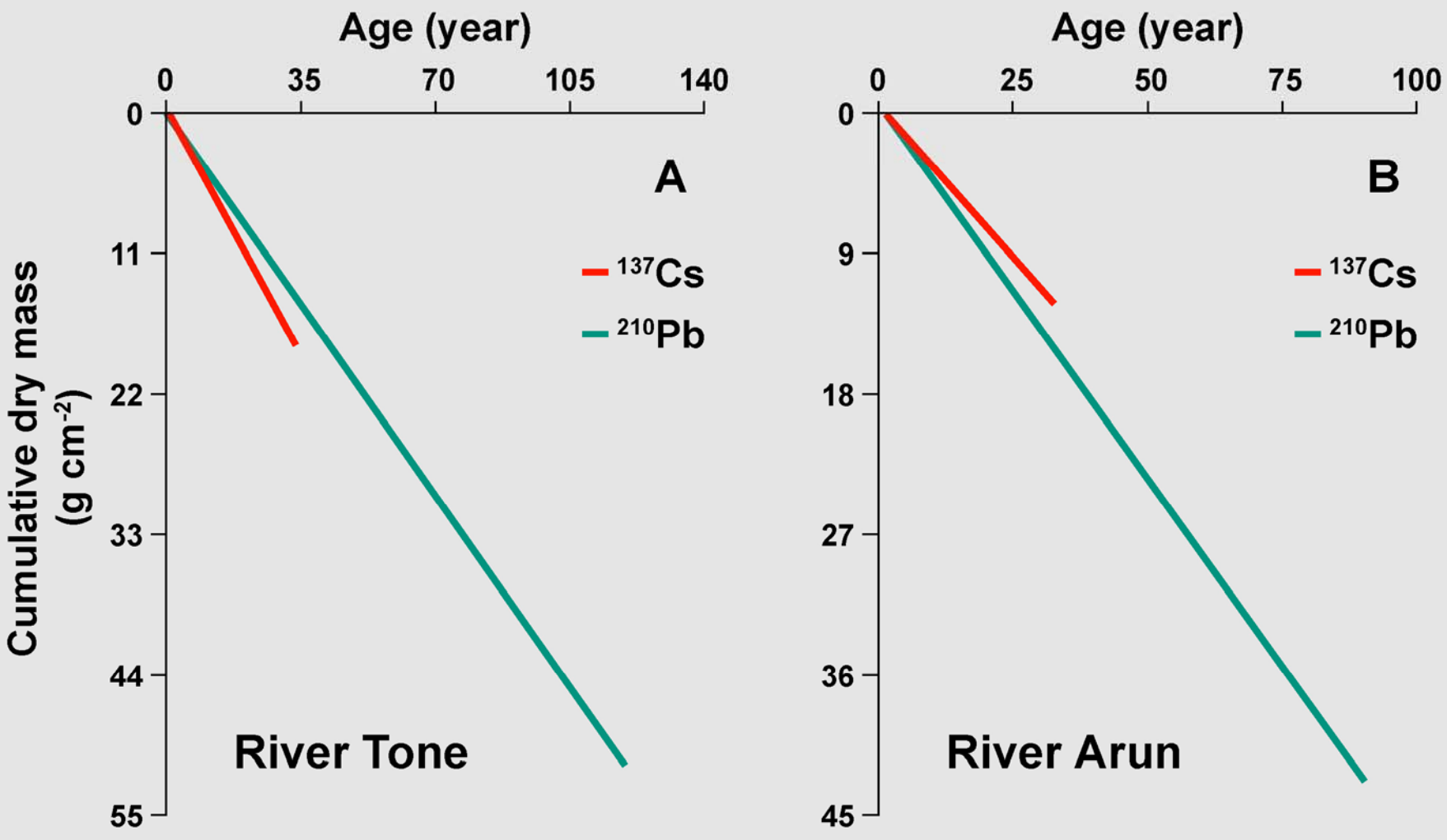
Woodland

CONCLUSIONS

- **Sediment monitoring**
- **Looking inside the black box**

Thank You


^{137}Cs activity
(mBq g^{-1})
Unsupported ^{210}Pb activity
(mBq g^{-1})
Cumulative dry mass
(g cm^{-2})
A
B
C
D
River Tone
River Tone
River Arun
River Arun
0
7
14
21
28
10
20
30
40
12
24
36
48
11
22
33
44
55
9
18
27
45


Age (year)
0
35
70
105
140
0
11
22
33
44
55
Cumulative dry mass
(g cm-2)
A
137Cs
210Pb
River Tone
Age (year)
0
25
50
75
100
0
9
18
27
36
45
B
137Cs
210Pb
River Arun

USE OF THE KRUSKAL-WALLIS TEST TO ASSESS THE ABILITY OF EACH TRACER PROPERTY TO DISCRIMINATE BETWEEN SURFACE (c. TOP 2 CM) SOIL FROM WOODLAND, UNCULTIVATED AND CULTIVATED AREAS AND CHANNEL BANK MATERIAL FROM THE OUSE AND WHARFE BASINS

Tracer property	H value*	P value
^{137}Cs (mBq g^{-1})	28.66	0.001†
^{226}Ra (mBq g^{-1})	17.20	0.001†
Unsupported ^{210}Pb (mBq g^{-1})	18.62	0.001†
N (%)	56.50	0.001†
C (%)	52.22	0.001†
Total P (µg g^{-1})	16.57	0.001†
Inorganic P (µg g^{-1})	12.04	0.007†
Organic P (µg g^{-1})	23.41	0.001†
χ_{lf} (µm^3 kg^{-1})	24.56	0.001†
χ_{fd} (nm^3 kg^{-1})	20.70	0.001†
SIRM (mAm^2 kg^{-1})	24.22	0.001†
Al (µg g^{-1})	9.73	0.021†
Ca (µg g^{-1})	6.62	0.086
Cr (µg g^{-1})	10.60	0.014†
Cu (µg g^{-1})	2.64	0.451
Fe (µg g^{-1})	17.03	0.001†
K (µg g^{-1})	12.19	0.007†
Mg (µg g^{-1})	11.67	0.009†
Mn (µg g^{-1})	21.16	0.001†
Na (µg g^{-1})	5.87	0.119
Ni (µg g^{-1})	22.10	0.001†
Pb (µg g^{-1})	3.52	0.319
Sr (µg g^{-1})	7.84	0.048†
Zn (µg g^{-1})	13.84	0.003†

* Critical H value = 7.82
† Significant at p = 0.05

USE OF STEPWISE DISCRIMINANT FUNCTION ANALYSIS TO IDENTIFY WHICH COMBINATION OF TRACER PROPERTIES PROVIDES THE BEST COMPOSITE FINGERPRINT FOR DISCRIMINATING SOURCE TYPES WITHIN THE OUSE AND WHARFE BASINS

Tracer property	Cumulative % samples classified correctly
N	51.90
Total P	74.29
Sr	77.94
Ni	82.35
Zn	83.82
^{226}Ra	83.82
^{137}Cs	88.24
Unsupported ^{210}Pb	88.24
Fe	92.65
Al	94.12