Sediment Fingerprinting and Bayesian Modelling in the River Wensum DTC

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Wensum Alliance

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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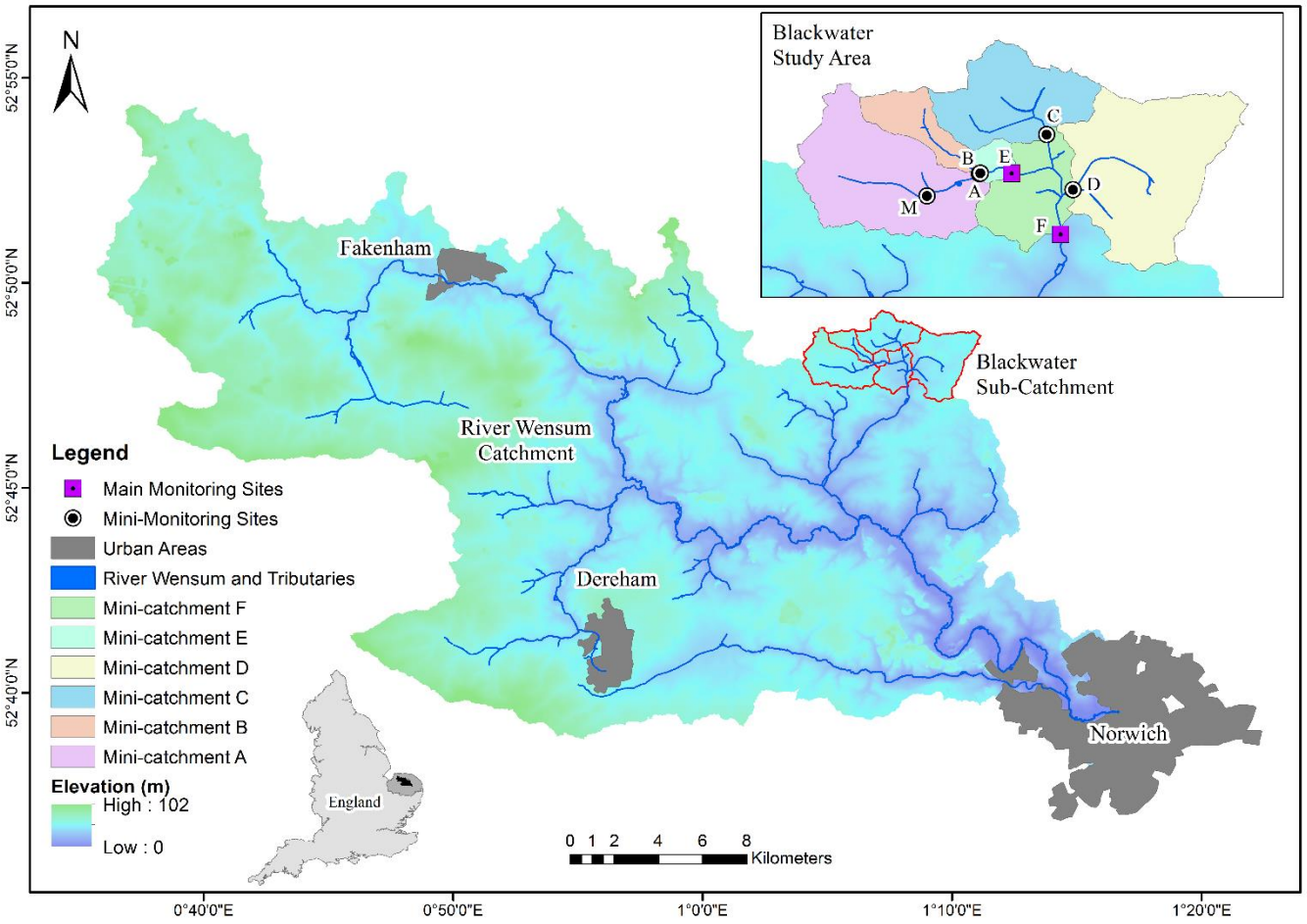
River Wensum DTC – Norfolk, Eastern England

- Length = **78 km**
- Catchment = **660 km²**
- Enriched, lowland calcareous system
- Groundwater dominated = **50-80%** of flow
- SSSI and SAC status
- 20 Sub-catchments
- Intensive monitoring of **20 km²** Blackwater sub-catchment



Blackwater sub-catchment

- Nitrates
- Phosphates
- Ammonia
- Turbidity
- Chlorophyll
- pH
- Conductivity
- Temperature
- Flow
- DO

Blackwater sub-catchment

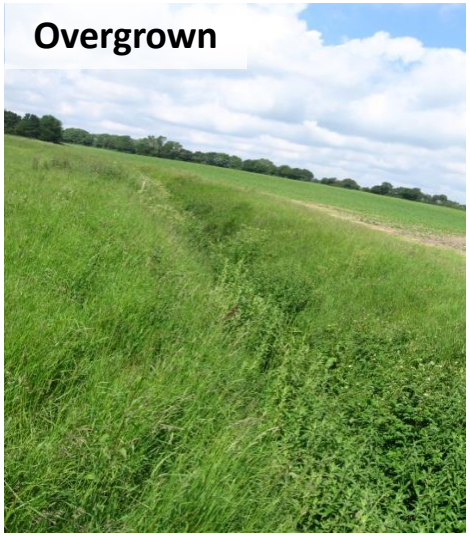
Blackwater sub-catchment:

- 90% Intensive Arable
  - ➢Wheat/ Barley/ Sugar beet/ Oilseed rape/ Beans
- 6 % Improved Grassland
- 2% Woodland
- 1% Urban

Enhanced land-to-river sediment transfers due to land management

Impacts on the River

Overgrown



Sedimentation

Smothering equipment

Algal films

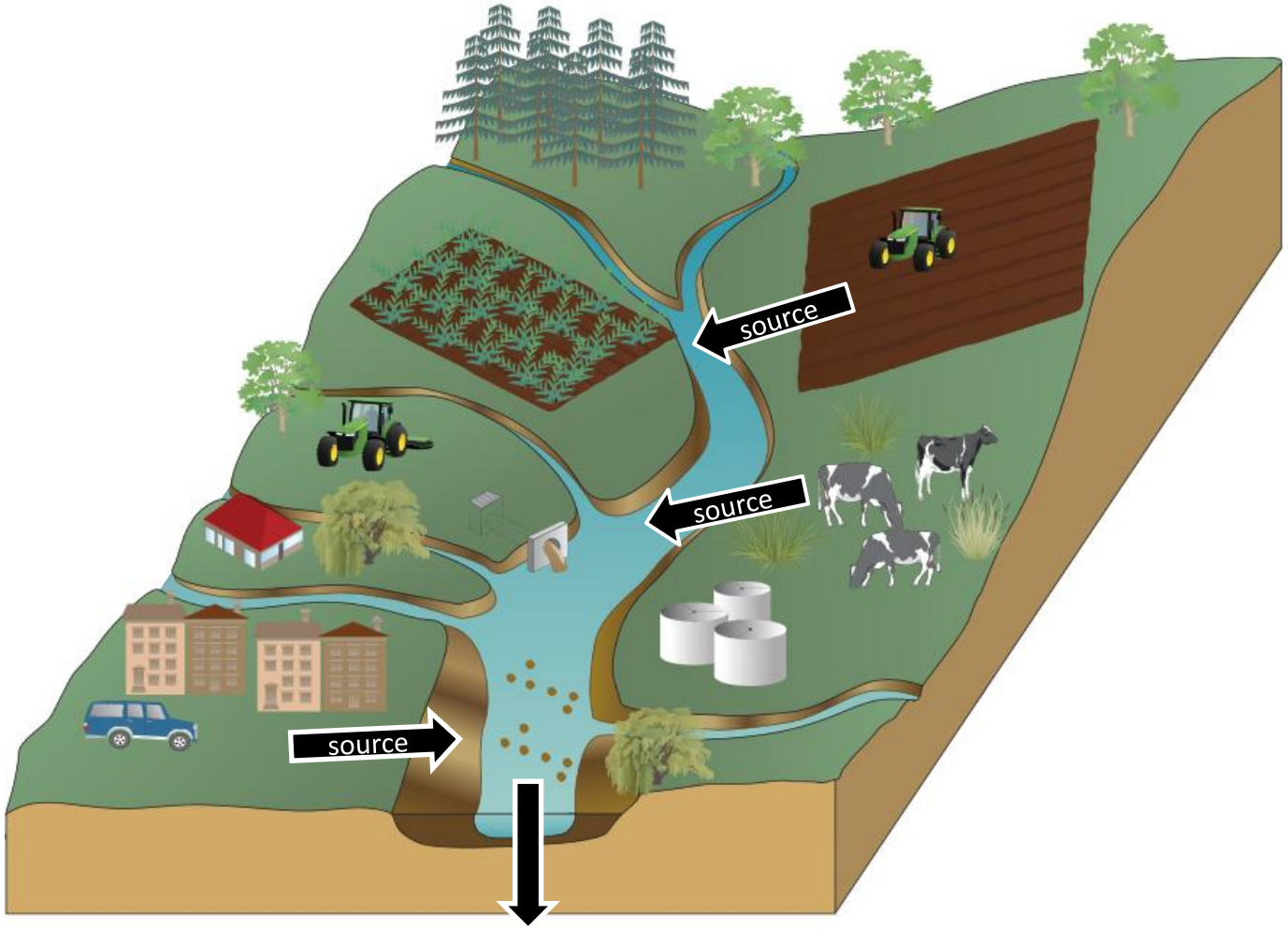
Turbidity

Benthic algae

Why is Sediment a Problem?

- Rivers affected by high sediment volumes suffer from:
  - Elevated turbidity
  - Smothering of benthic habitats
  - Loss of spawning gravels
  - Damage to fish gills
  - Eutrophication
  - Dredging costs
- Essential to understand sediment sources to enable mitigation measures to be targeted accordingly.
- Sediment fingerprinting can assist with apportionment.

What is Sediment Fingerprinting?



Suspended sediment geochemistry

Primary Research Aims

- Develop high-temporal resolution fluvial sediment source apportionment technique.
  - How to **improve the temporal resolution** of source apportionment estimates whilst minimising analytical costs.
  - How to **consistently quantify all perceived uncertainties** associated with the sediment mixing model procedure.

What are the Possible Sources?

Channel Banks

Arable Topsoils

Suspended Sediments

Field Drains

Road Verges

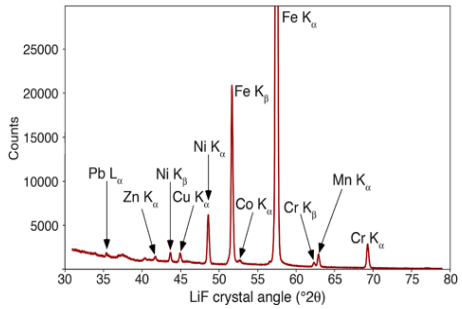
Collecting Sediments

- Instream **suspended sediment** samples collected from sites A, B & E during heavy rainfall events (>10 mm) via **ISCO automatic samplers**.

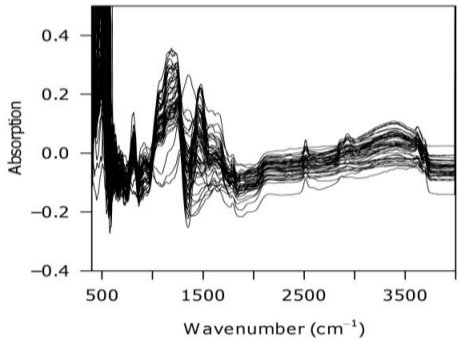
- Sediment samples collected from each of the **4 potential source areas** – surface scrapes (<50 mm) and grab samples.
  - ➢ Target **critical source areas**.

Analysing Sediment Geochemistry

All samples sonicated, wet sieved <63 µm, and vacuum filtered through **quartz fibre filter (QFF) papers**.



XRFS: X-ray Fluorescence Spectroscopy (Al, Ca, Ce, Fe, K, Mg, Mn, Na, P, Si, Ti) - '**Geochemical Fingerprints**'.



DRIFTS: Diffuse Reflectance Infra-red Spectroscopy - Organic Carbon, Fe/Al oxyhydroxides

- **Rapid**, **accurate**, **inexpensive** and **non-destructive** – contrast with ICP, acid digestion, LOI etc….

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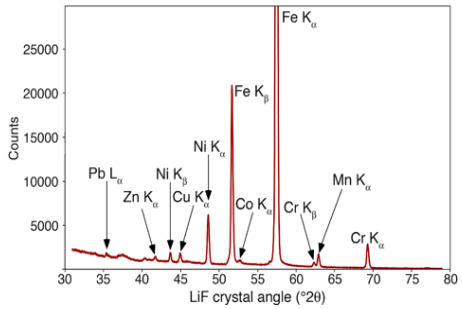

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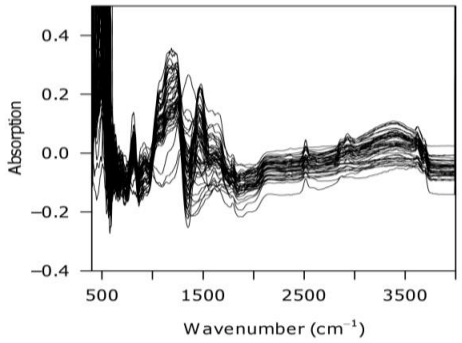

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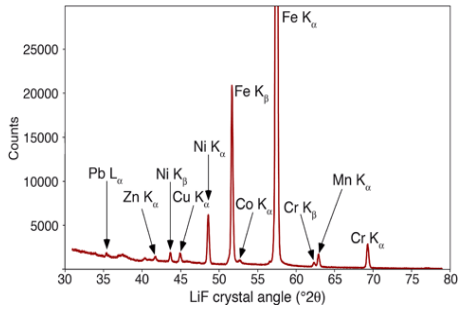

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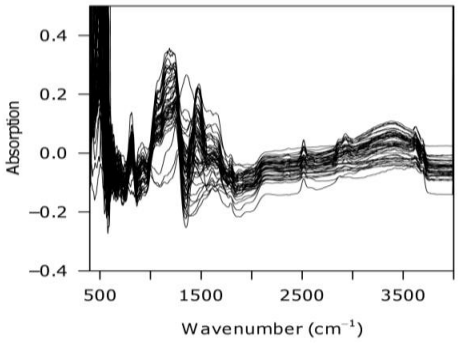

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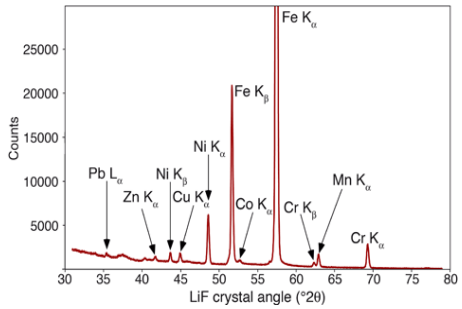

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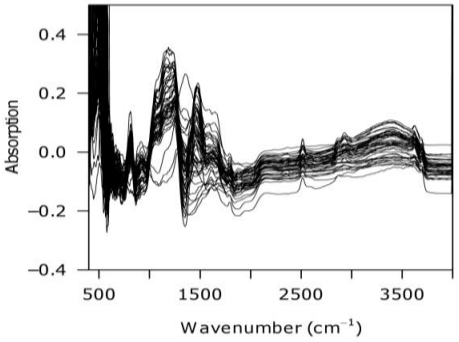

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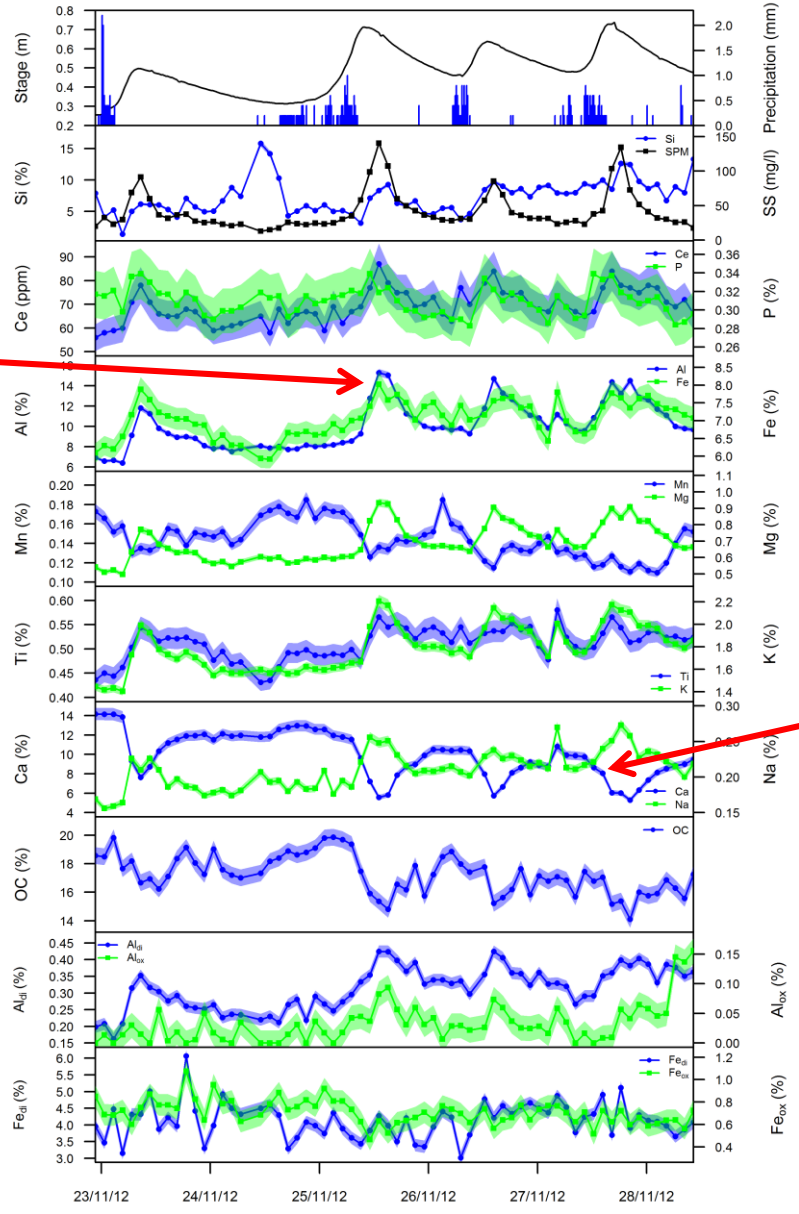
High-resolution time series

Peaks in clay-mineral associated elements during rainfall – indicative of surface sources



60-120 minute resolution

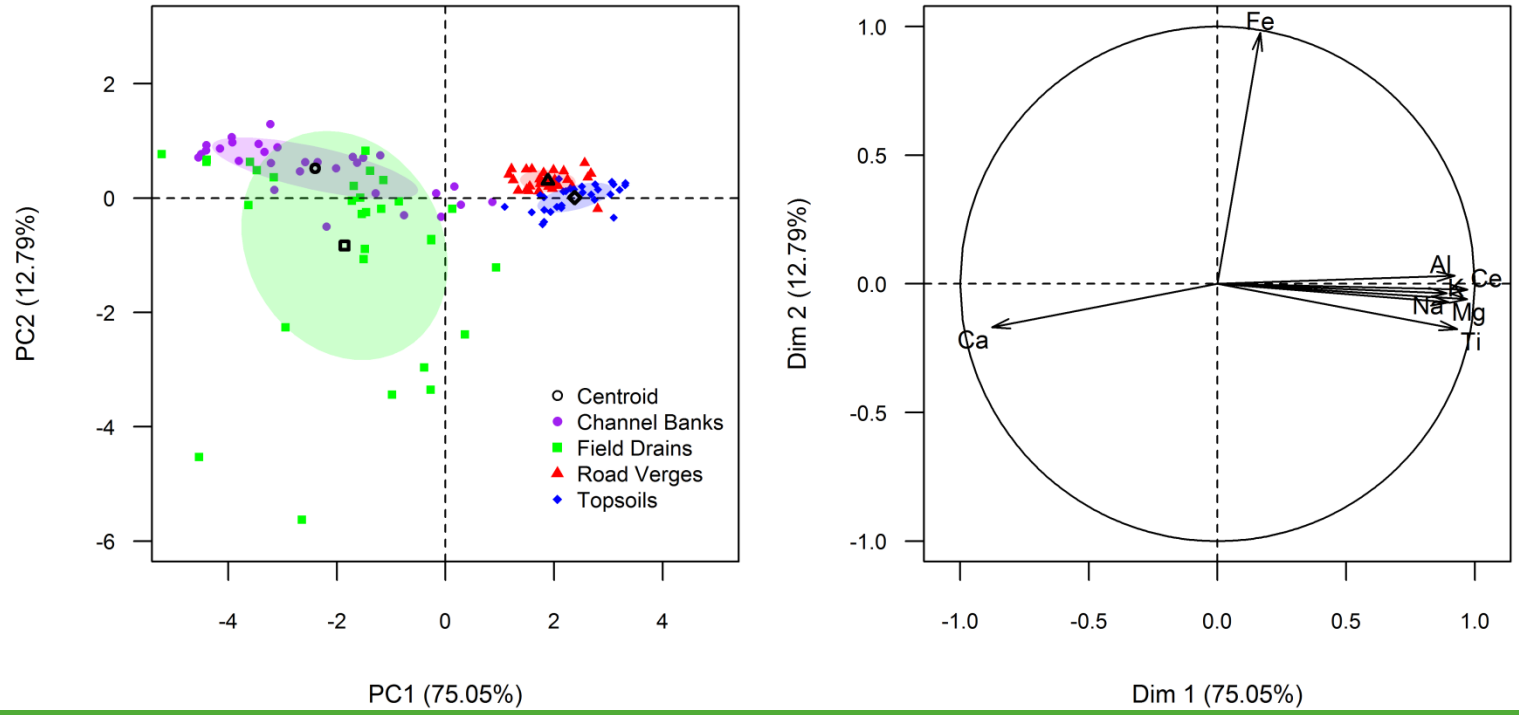
Decline in Ca – reduced importance of subsurfaces

Identifying Fingerprints

- **Principal components analysis (PCA)** and **Linear Discriminant Analysis (LDA)** to determine geochemical fingerprints capable of differentiating the source areas.

- 8 geochemical fingerprints selected (**Ca, K, Mg, Al, Ce, Fe, Na, Ti**).

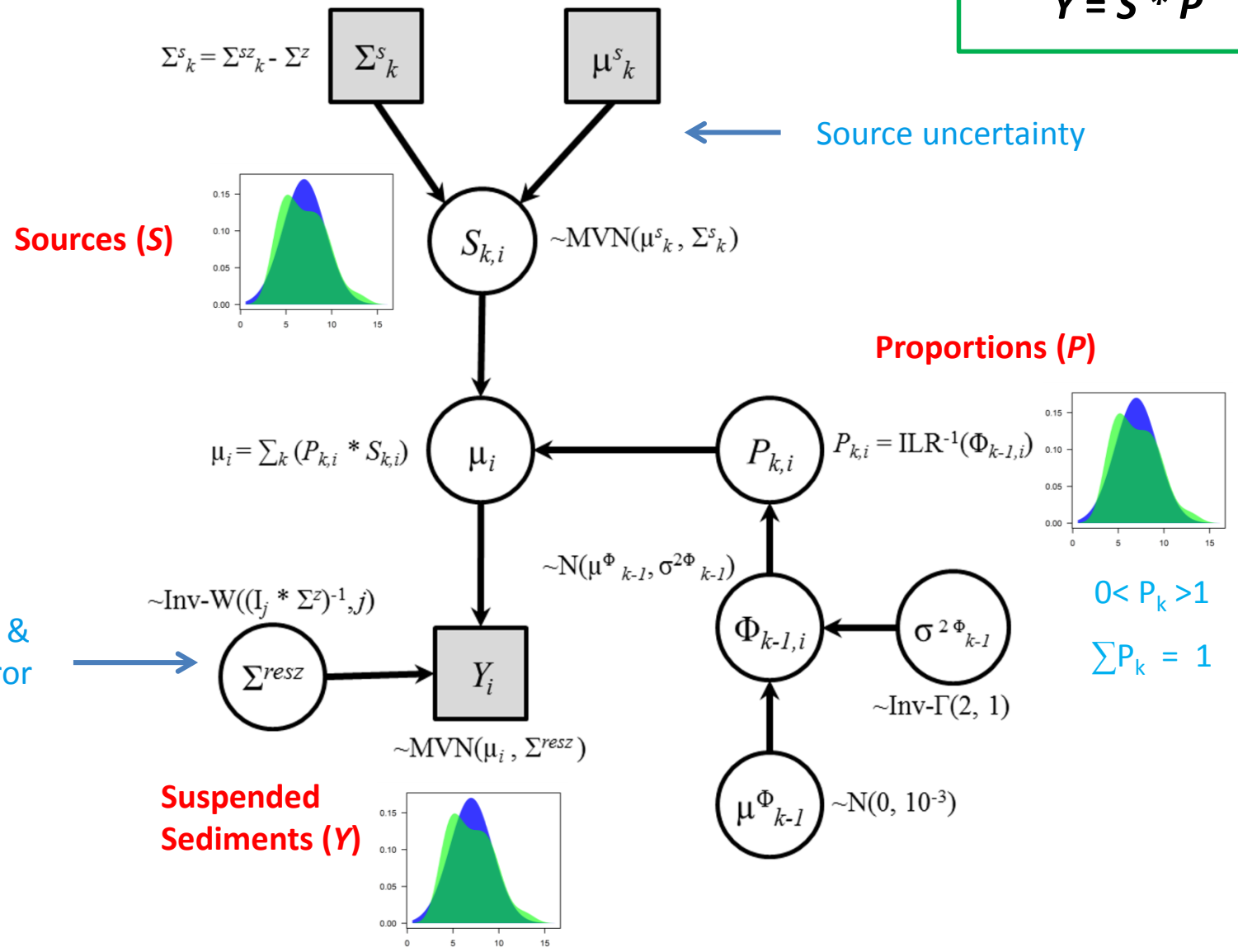
- **Channel bank** and **field drain** data merged into a combined **subsurface** sediment source.



Bayesian Mixing Model

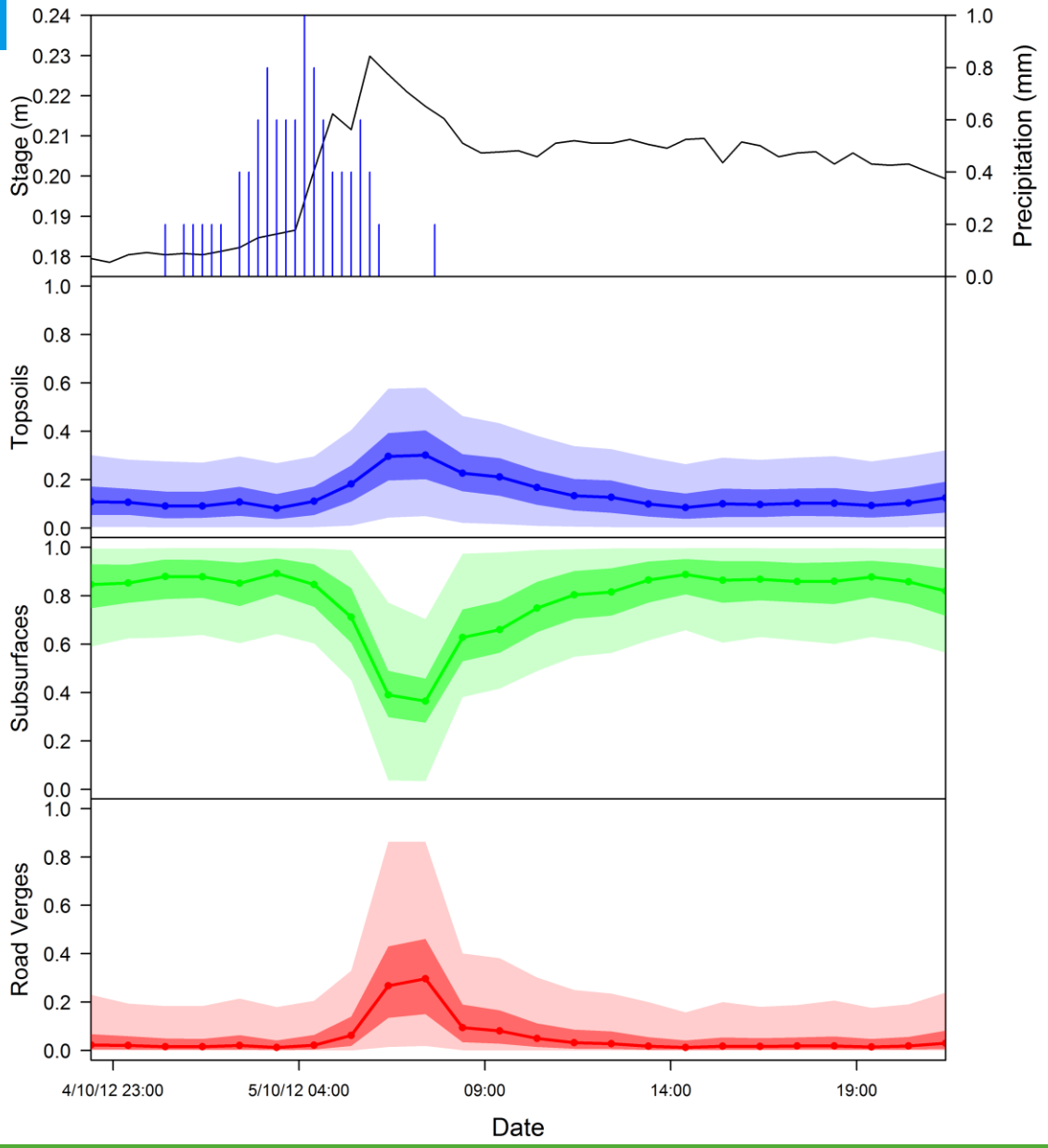
Gibbs Sampling Markov-chain Monte-Carlo procedure

$$Y = S * P$$



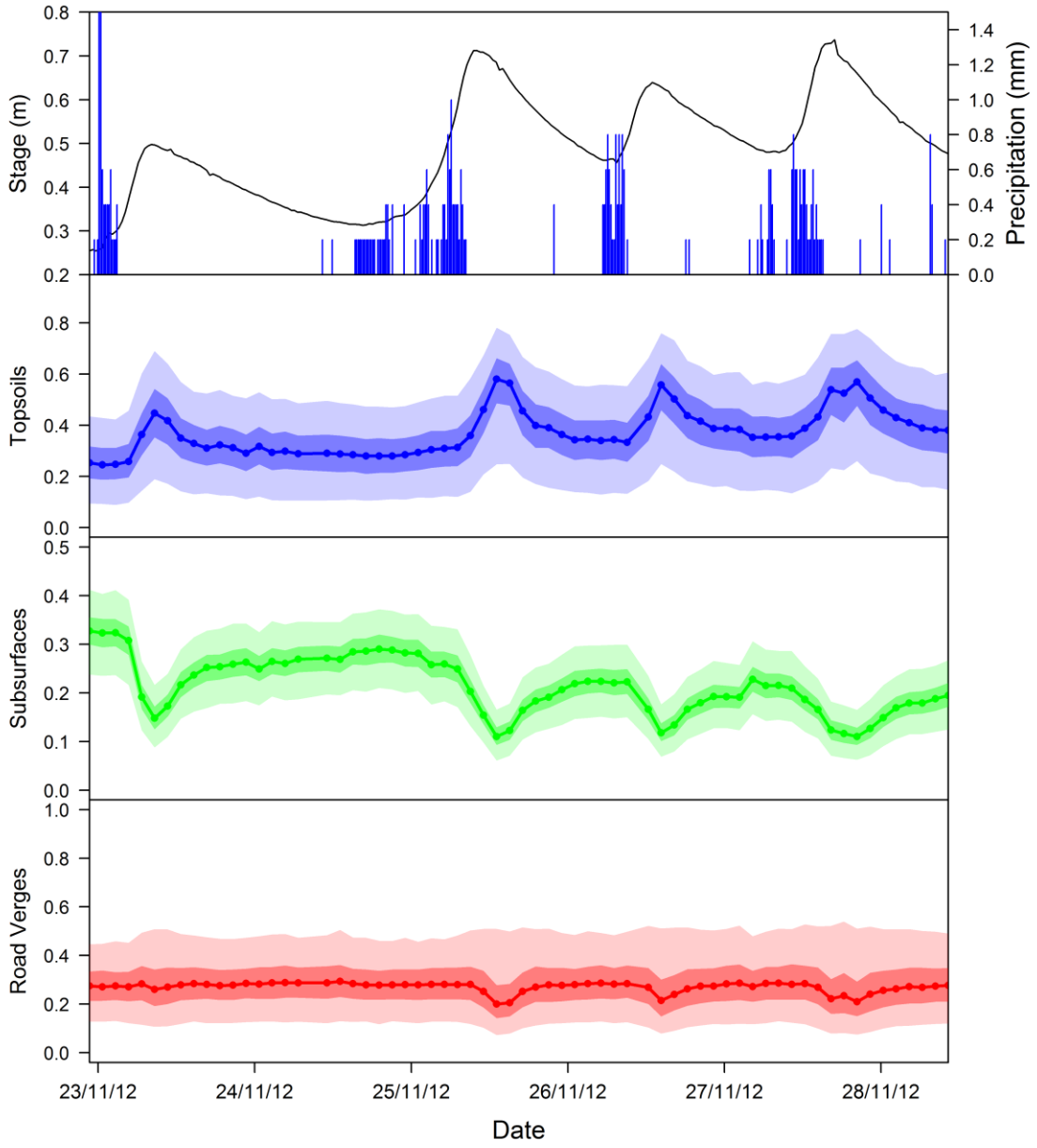
4-5th October 2012

- **10.2 mm** rainfall
- Response **2 hours** after onset of heaviest rainfall.
- **Subsurface** calcium-rich material dominates pre- & post-event.
- Rapid increase in carbonate-depleted **Topsoil** and **Road Verge** contribution as surface runoff generated.



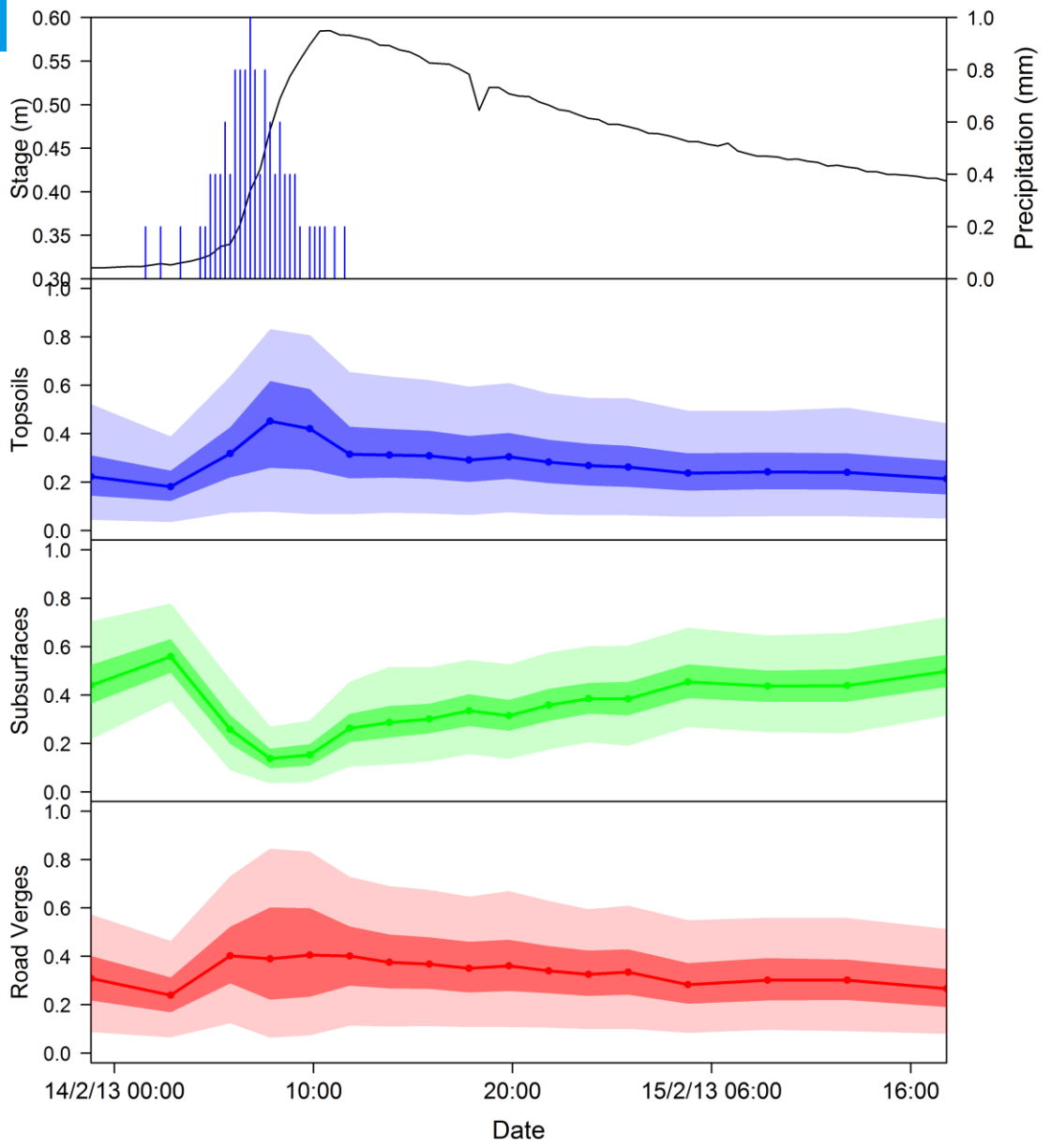
24-28th November 2012

- **36.4 mm** rainfall
- **Increase** in **Topsoil** contribution as rainfall events pass through the catchment generating surface runoff.
- **Declining** contribution from **subsurface sources** as successive precipitation episodes increase importance of surface sources.



14-15th February 2013

- **12.8 mm** rainfall
- Similar pattern to previous events.
- Large increase in **Topsoil** and **Road Verge** contribution within first few hours.
- **Subsurface sources** less important as land-to-river sediment transfer increases.



The Main Problem?

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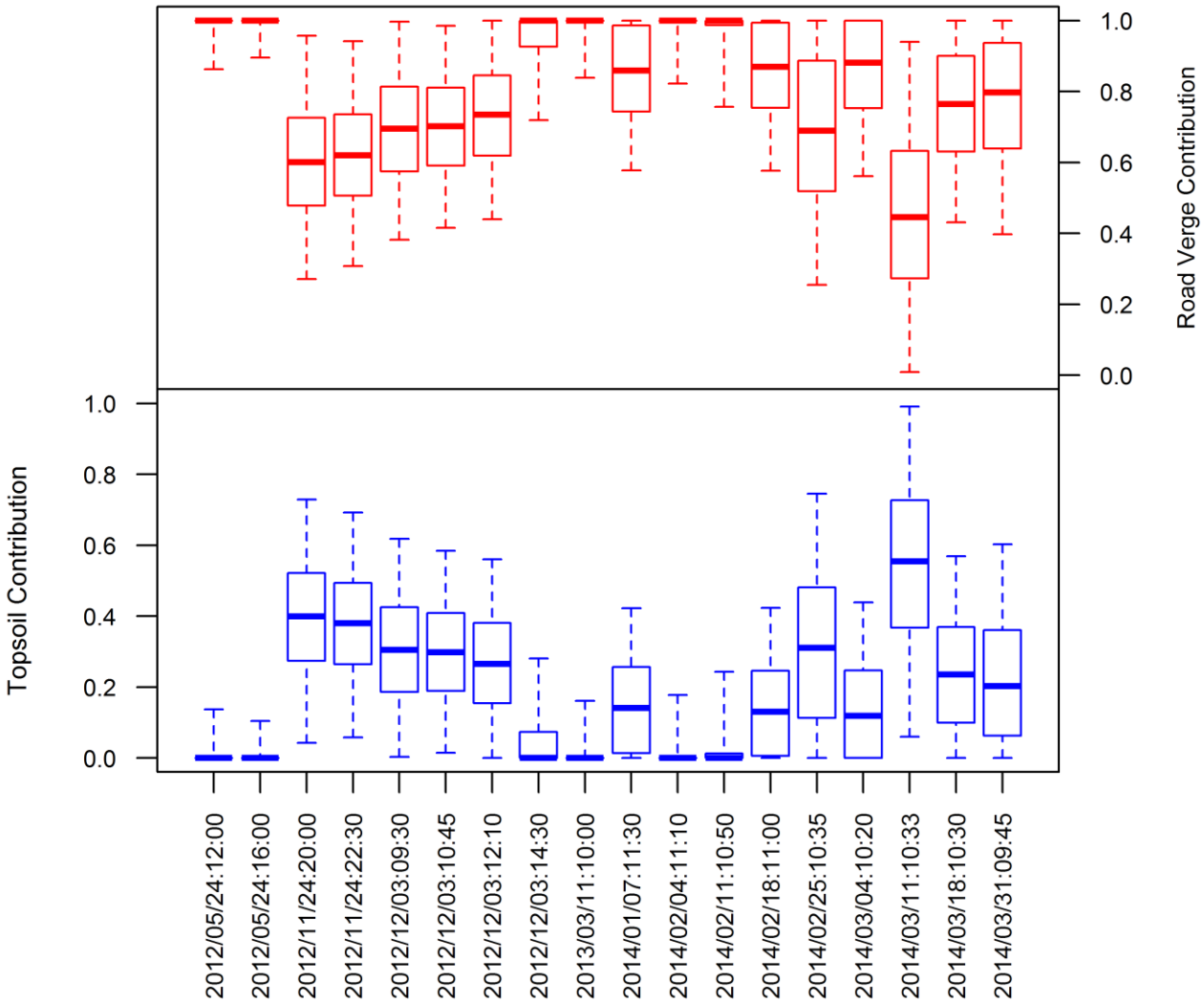
Road Runoff


Topsoil Contribution
Road Verge Contribution
0.0
0.2
0.4
0.6
0.8
1.0
2012/05/24:12:00
2012/05/24:16:00
2012/11/24:20:00
2012/11/24:22:30
2012/12/03:09:30
2012/12/03:10:45
2012/12/03:12:10
2012/12/03:14:30
2013/03/11:10:00
2014/01/07:11:30
2014/02/04:11:10
2014/02/11:10:50
2014/02/18:11:00
2014/02/25:10:35
2014/03/04:10:20
2014/03/11:10:33
2014/03/18:10:30
2014/03/31:09:45

Potential Solutions?

- Cover crops

- Management of Field Entrances

Take Home Messages

- Spectroscopy provides **rapid**, **accurate**, **inexpensive** and **non-destructive** method for high-temporal resolution sediment source apportionment.

- The **Bayesian mixing model** procedure provides a coherent framework to quantify all perceived uncertainties.

- **Subsurface** material dominates under lower flow pre- & post-event conditions.

- **Surface source** inputs increase during rainfall – metalled road appear to increase field-to-river connectivity.

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Thank You for Listening

HYDROLOGICAL PROCESSES
Hydrol. Process. **28**, 4042–4056 (2014)
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Combining two filter paper-based analytical methods to monitor temporal variations in the geochemical properties of fluvial suspended particulate matter

R. J. Cooper,[1]* B. G. Rawlins,[2] B. Lézé,[1] T. Krueger[1] and K. M. Hiscock[1]
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EARTH SURFACE PROCESSES AND LANDFORMS
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ESPL
Earth Surface Processes and Landforms

High-temporal resolution fluvial sediment source fingerprinting with uncertainty: a Bayesian approach

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[1] School of Environmental Sciences, University of East Anglia, Norwich, UK
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