Determining sources of soil erosion using Compound Specific Isotope Analysis;
An initial assessment in a rural Australian catchment

24 July 2012    Gary Hancock and Andrew Revill
Overview

• Assess ability of CSIA to discriminate soil erosion sources
• Determine soil sources during a high flow event (January 2008)
• Compare results with fallout radionuclide and geochemical tracing
Typical erosion sources in a rural catchment:
Surface soil (A-horizon) sources

Grazed open woodland

Cleared pasture

Closed canopy forest
Typical erosion sources in a rural catchment: Sub-surface soil (B-horizon) sources

Hillslope scalds and incised drainage lines
Typical erosion sources in a rural catchment: Cultivated soil sources

Irrigated and dry-land crops
Typical erosion sources in a rural catchment; In-stream channel sources

Channel scour and bank collapse
CSSI tracing
Attachment of fatty acids and organic carbon to soil particles

Organic matter decomposition
Fatty acid leaching

soil particle
organic coating
CSSI analysis procedure

**Sample collection + preparation**
- Combining of many samples
- Sub-sampling
- Drying
- Sieving (< 63 μm)

**Separation of fatty acids**
- Extraction (sonicating) with CH₂Cl₂-MeOH
- Solvent removal
- Addition of HCl

**Derivatisation**
- Conversion of fatty acids to their methyl esters

**Compound Specific Isotope Analysis**
- Gas Chromatography
- Mass spectrometry measurement of δ¹³C
Logan-Albert catchment

Tropic of Capricorn

Logan-Albert 3700 km²
Logan-Albert catchment land-uses

Catchment area 3700 km²
Logan-Albert soil sampling locations

- Pasture
- Forest
- Channel Bank
- Subsoils
- Cultivated
Fatty acid concentrations

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>Concentration (ug g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C12:0</td>
<td></td>
</tr>
<tr>
<td>C14:0</td>
<td></td>
</tr>
<tr>
<td>C15:0</td>
<td></td>
</tr>
<tr>
<td>i15:0</td>
<td></td>
</tr>
<tr>
<td>C16:0</td>
<td></td>
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<tr>
<td>i16:0</td>
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<tr>
<td>C16:1w7</td>
<td></td>
</tr>
<tr>
<td>C18:0</td>
<td></td>
</tr>
<tr>
<td>C18:1w9</td>
<td></td>
</tr>
<tr>
<td>C18:1w7</td>
<td></td>
</tr>
<tr>
<td>C20:0</td>
<td></td>
</tr>
<tr>
<td>C22:0</td>
<td></td>
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<td>C24:0</td>
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<td>C25:0</td>
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<tr>
<td>C26:0</td>
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<tr>
<td>C28:0</td>
<td></td>
</tr>
<tr>
<td>C30:0</td>
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</tr>
</tbody>
</table>

Legend:
- Pasture
- Cultivated
- Channel bank
- Forest
- Subsoil
Soil source fatty acid proportions C14 to C18

![Bar chart showing fatty acid proportions and bulk carbon for different soil sources: Pasture, Cultivated, Channel bank, Forest, Subsoil. The x-axis represents average fatty acids and bulk carbon, while the y-axis represents fatty acid proportion and bulk C (%). The chart compares the fatty acid proportions and bulk carbon across different soil types.]
Fatty acid $\delta^{13}C$

- Bulk C-13
- C14:0
- i15:0
- C16:1w7
- C16:0
- C18:0

Channel Bank
Cultivated
Forest
Pasture
Subsoils

$\delta^{13}C$ (%)
CSSI soil source discrimination – T values

T values >5 are highlighted (corresponding to p<0.01)

<table>
<thead>
<tr>
<th>Soil source pairs</th>
<th>Bulk $\delta^{13}$C</th>
<th>C12:0</th>
<th>C14:0</th>
<th>i15:0</th>
<th>a15:0</th>
<th>i16:0</th>
<th>C16:1w7</th>
<th>C16:0</th>
<th>18 comb</th>
<th>C18:0</th>
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</thead>
<tbody>
<tr>
<td>Pasture:Forest</td>
<td>9.4</td>
<td>6.4</td>
<td>19.1</td>
<td>17.0</td>
<td>9.8</td>
<td>16.6</td>
<td>8.2</td>
<td>12.2</td>
<td>15.2</td>
<td>12.6</td>
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<tr>
<td>Pasture:Cultivated</td>
<td>4.0</td>
<td>2.0</td>
<td>7.7</td>
<td>6.2</td>
<td>7.2</td>
<td>6.3</td>
<td>11.5</td>
<td>5.5</td>
<td>4.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Pasture:Chan Bk</td>
<td>8.9</td>
<td>0.7</td>
<td>3.4</td>
<td>2.8</td>
<td>4.6</td>
<td>3.8</td>
<td>4.5</td>
<td>2.7</td>
<td>5.8</td>
<td>4.4</td>
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<tr>
<td>Pasture:Subsoils</td>
<td>5.9</td>
<td>0.5</td>
<td>0.1</td>
<td>9.5</td>
<td>8.7</td>
<td>2.0</td>
<td>4.3</td>
<td>3.1</td>
<td>4.4</td>
<td>2.7</td>
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<td>Forest:Cultivated</td>
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<td>16.1</td>
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<td>11.0</td>
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<td>Forest:Subsoils</td>
<td>3.6</td>
<td>6.4</td>
<td>18.3</td>
<td>14.1</td>
<td>3.1</td>
<td>8.5</td>
<td>0.4</td>
<td>3.5</td>
<td>4.1</td>
<td>3.5</td>
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<td>Chan Bk:Cultivated</td>
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<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>1.3</td>
<td>2.1</td>
<td>6.6</td>
<td>3.4</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Chan Bk:Subsoils</td>
<td>0.6</td>
<td>0.9</td>
<td>3.4</td>
<td>0.6</td>
<td>0.5</td>
<td>2.4</td>
<td>2.5</td>
<td>1.3</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Cultivated:Subsoils</td>
<td>1.8</td>
<td>2.2</td>
<td>7.1</td>
<td>0.5</td>
<td>1.3</td>
<td>1.1</td>
<td>0.2</td>
<td>1.5</td>
<td>0.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Fatty acid $\delta^{13}$C – soil source discrimination
Fatty acid $\delta^{13}C$ – soil source discrimination

- Stearic Acid (C18:0)
- Myristic Acid (C14:0)
- Palmitic Acid (C16:0)

Channel bank
Forest
Pasture
Cultivated
Subsoils
Forest gully

-36 -34 -32 -30 -28 -26 -24 -22 -20 -18
-16 -14 -12 -10 -8 -6 -4 -2 0

Stearic Acid (C18:0)
Myristic Acid (C14:0)
Palmitic Acid (C16:0)
Sample collection for sediment source tracing in the Logan-Albert catchments

January 2008 flood event:
200-350 mm rain over 48 hr period:
1 in 10 year event
January 2008: sampling of overbank deposits of sediment
IsoSource

All possible combinations of each soil source (0-100%) are examined in small increments. Combinations that sum to the observed sediment isotopic signature within a given tolerance (e.g., ±1 ‰) are considered to be feasible solutions.

IsoSource output for Lower Logan – 5 soil sources

Lower Logan

Proportion (%)

Frequency

Channel Bank
Cultivated
Forest
Pasture
Subsoils (cks)

Channel bank

Pasture

Subsoils

n = 189
Conversion to % soil source

\[
\%Soil_{source}\_n = \frac{(P_n / C_n)}{\sum_{n}(P_n / C_n)} \times 100
\]

<table>
<thead>
<tr>
<th></th>
<th>Bulk C (%)</th>
<th>IsoSource (\text{carbon sources}) (%)</th>
<th>Soil sources (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Logan</strong></td>
<td></td>
<td></td>
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<tr>
<td>Channel bank</td>
<td>1.26</td>
<td>68 ±4</td>
<td>72 ±4</td>
</tr>
<tr>
<td>Cultivated</td>
<td>3.14</td>
<td>2 ±2</td>
<td>1 ±1</td>
</tr>
<tr>
<td>Forest</td>
<td>7.72</td>
<td>1 ±1</td>
<td>&lt; 1</td>
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<tr>
<td>Pasture</td>
<td>4.35</td>
<td>20 ±2</td>
<td>7 ±2</td>
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<tr>
<td>Subsoils</td>
<td>0.59</td>
<td>9 ±2</td>
<td>20 ±4</td>
</tr>
<tr>
<td></td>
<td>Forest</td>
<td>Pasture</td>
<td>Cultivated</td>
</tr>
<tr>
<td>---------------------</td>
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<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>CSIA</td>
<td>&lt; 1</td>
<td>7 ±1</td>
<td>&lt; 2</td>
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<tr>
<td>Fallout tracers</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Surface soil</td>
<td>10 ±5</td>
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<tr>
<td>Sub-surface soil</td>
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</tbody>
</table>
Specific sub-catchments
Cannon Creek

Cannon Creek

Hillslope subsoil carbon
48 ±5%

Proportion (%)
Specific sub-catchments

>90% Lamington volcanics

Lower Albert

Forest 78 ±3%
Conclusions

• CSIA provides excellent discrimination in a sub-tropical climate between land-uses characterised by grassed vegetation (pasture) and wooded vegetation (forest).

• Other erosion sources can also be discriminated – including sub-surface soil sources (channel bank and hillslope scalds/gullies cultivated soils).

• In this study the combination of CSIA, fallout tracers and element geochemistry has allowed the identification of major sediment sources by their spatial distribution, land-use, and erosion process.
Thank you