



Review

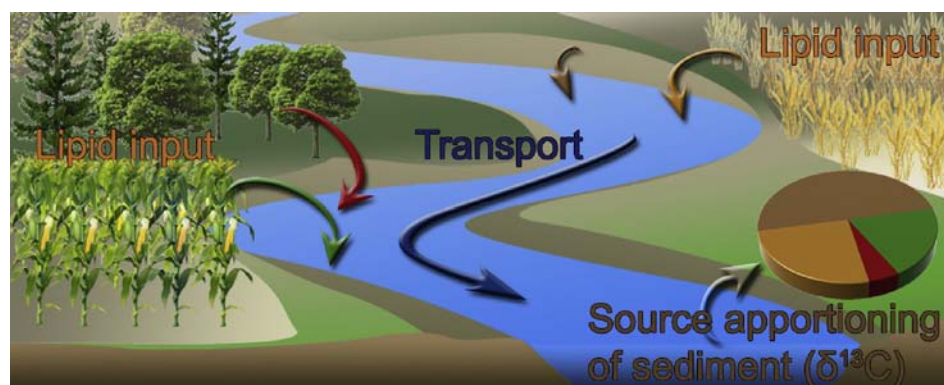
Sources of variability in fatty acid (FA) biomarkers in the application of compound-specific stable isotopes (CSSIs) to soil and sediment fingerprinting and tracing: A review

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HIGHLIGHTS

- Compound-specific stable isotopes (CSSIs) of carbon may be used as soil tracers.
- The variables affecting CSSI data are: biological, environmental and analytical.
- Understanding sources of variability will lead to more robust methods and data.
- Recommendations for applying CSSIs to soil and sediment tracing are provided.

GRAPHICAL ABSTRACT



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ABSTRACT

Determining soil redistribution and sediment budgets in watersheds is often challenging. One of the methods for making such determinations employs soil and sediment fingerprinting techniques, using sediment properties such as geochemistry, fallout radionuclides, and mineral magnetism. These methods greatly improve the estimation of erosion and deposition within a watershed, but are limited when determining land use-based soil and sediment movement. Recently, compound-specific stable isotopes (CSSIs), which employ fatty acids naturally occurring in the vegetative cover of soils, offer the possibility of refining fingerprinting techniques based on land use, complementing other methods that are currently in use.

The CSSI method has been met with some success; however, challenges still remain with respect to scale and resolution due to a potentially large degree of biological, environmental and analytical uncertainty. By better

Abbreviations: PSE, pressurized solvent extraction; BMP, beneficial or best management practice; CAM, Crassulacean acid metabolism; CSSI, compound-specific stable isotope; CV, coefficient of variation; DSP, diffuse source pollution; EA, elemental analyzer; FA, fatty acid; FAME, fatty acid methyl ester; FID, flame ionization detector; FRN, fallout radionuclide; GC, gas chromatography; GC-C, gas chromatography-combustion; IRMS, isotope ratio mass spectrometer; KIE, kinetic isotope effect; LOI, loss on ignition; NLFA, neutral lipid fatty acid; OC, organic carbon; OM, organic matter; PAH, polyaromatic hydrocarbon; PEP, phosphoenolpyruvate; PLFA, phospholipid fatty acid; rubisco, ribulose bis-phosphate carboxylase; SD, stomatal density; SOC, soil organic carbon; SOM, soil organic matter; SOP, standard operating procedure; TAG, triacylglycerol; TOC, total organic carbon; TT, thermally treated; VLCFA, very long-chain fatty acid; VOC, volatile organic carbon; V-PDB, Vienna-Pee Dee Belemnite; WB, Walkley-Black; WUE, water use efficiency.

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understanding the source of tracers used in CSSI work and the inherent biochemical variability in those tracers, improvement in sample design and tracer selection is possible. Furthermore, an understanding of environmental and analytical factors affecting the CSSI signal will lead to refinement of the approach and the ability to generate more robust data. This review focuses on sources of biological, environmental and analytical variability in applying CSSI to soil and sediment fingerprinting, and presents recommendations based on past work and current research in this area for improving the CSSI technique. A recommendation, based on current information available in the literature, is to use very-long chain saturated fatty acids and to avoid the use of the ubiquitous saturated fatty acids, C₁₆ and C₁₈.

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Contents

1.	Soil and sediment fingerprinting: an overview	9
1.1.	Water security and ecosystem health	9
1.2.	Policy	10
1.3.	Composite fingerprinting, tracing, and apportioning soil and sediments	10
2.	CSSI tracing: the promise of a new technique	11
2.1.	Soil and sediment fingerprinting: the role of CSSIs	11
2.2.	Determination of delta (δ) shifts for isotopic ratios of carbon	11
3.	Plant-derived biomarkers	13
3.1.	Biomarker criteria and sources	13
3.2.	Plants: a good source of FA biomarkers	13
4.	Sources of isotopic variability during FA synthesis	13
4.1.	Biological factors	13
4.1.1.	Plants and isotopic fractionation	14
4.1.2.	Production of FAs and related compounds	14
4.2.	Environmental factors	15
4.2.1.	Water use efficiency (WUE)	15
4.2.2.	Altitude	15
4.2.3.	Canopy height, leaf age and branch length	15
4.2.4.	Other factors	16
5.	Soil organic carbon and lipids	17
5.1.	Lipids and the soil environment	17
5.2.	Persistence of FAs and soil aggregation	18
5.2.1.	Consequences of soil aggregates and accessing FA biomarkers	18
5.3.	Biomarkers on (in) the horizon	19
5.4.	Soil organic carbon: a dynamic environment	19
6.	Reducing uncertainty during sample handling and analysis	20
6.1.	Storage and pre-extraction processing	21
6.2.	Extraction of lipids and isotopic fractionation	21
6.3.	Purification	21
6.4.	Derivatization of FAs to FAMES	21
6.5.	Isotopic fractionation during GC-C-IRMS analysis	22
7.	Summary and conclusions	22
7.1.	Recommendations	23
7.2.	Perspective	24
	Acknowledgements	25
	References	25

1. Soil and sediment fingerprinting: an overview

1.1. Water security and ecosystem health

Rivers are the primary source of renewable fresh water supply (Vörösmarty et al., 2010), and thus are fundamental for ensuring water security. The activities of landholders have been identified as one of the water management factors that contribute to the degradation of water quality (Sarker et al., 2008). In the United States, agricultural fields have been determined to be the greatest contributor to diffuse source pollution (DSP) (Pimentel et al., 2004), resulting in water quality loss due to soil erosion and run-off of nutrients, sediments and pesticides (Pimentel et al., 2004; Sarker et al., 2008); indeed, agricultural land use has been found to be the predominant stressor on catchments globally (Vörösmarty et al., 2010). A need therefore exists to address and manage the DSPs that lead to water quality degradation and threaten water security.

Although some aquatic organisms may be tolerant and able to adapt to a range and highly variable amount of fine sediment (Henley et al., 2000), increased fine sediment¹ loads entering a body of water may have undesirable chemical and physical effects on the aquatic environment. Physical effects include a decrease in light penetration, accumulation of sediment leading to decreased accessibility of waterways, and increased purification costs if the water body is being used as a drinking source (Owens et al., 2005; Bilotta and Brazier, 2008; Horowitz, 2008). An increase in sediment deposition is also an indication of terrestrial erosion and soil loss (Horowitz, 2008). Human activities such as deforestation, agriculture, construction and mining have been shown to be major contributors to increased deposition and transport of fine

¹ Finer particle sizes are more apt for suspension and transport in aquatic systems; particle sizes of <63 μm are important for the transport and storage of contaminants and nutrients (Owens et al., 2005).

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