Sediment fingerprinting - Compound specific stable isotope analysis of long chain fatty acids (LCFAs) to trace sediment origin and connectivity of sediment sources to freshwater systems: case of the Baldegg Lake catchment (CH)

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Duration: Since 2015 – ongoing

Slope destabilization and associated sediment transfer are one of the major causes of aquatic ecosystems and surface waters quality impairment. Through land uses and agricultural practices, human activities modify the soils erosive risk and the catchments sedimentary connectivity, becoming a key factor of sediment dynamics. Hence, restoration and management plans of water bodies can only be efficient if the sediment sources and their respective contributions, and thus the proportion attributable to different land uses and agricultural practices, are identified.

Sediments can be traced, from their source to their deposition zone, using fingerprinting tools.

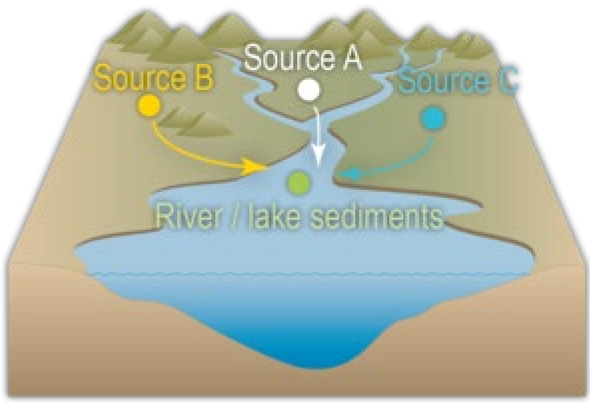

Figure 1: Fingerprinting concept - Catchment symbol: Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

1. Compound Specific Isotope Analysis (CSIA)

Classic fingerprinting techniques (e.g. magnetism, elemental composition, sediment color, radionuclides, $\delta^{15}N$ bulk, Fig. 1) are not adapted at providing information about the contribution of different land uses to erosion. A new technique, using the compound specific stable isotope (CSSI) signatures of inherent organic biomarkers in the soil (in this project: fatty acids, FAs), is developed since a few years (Gibbs, 2008; Blake et al., 2012; Hancock et Revill, 2013; Cooper et al., 2015; Alewell et al., 2016; Reiffarth et al., 2016). Although all plants produce the same FAs, the carbon stable isotopic signature ($\delta^{13}C$) of those biomarkers is different for each plant species. Because of their polar nature, FAs are easily leached from the plant or the decaying plant material and become tightly bound to soil particles. Coupled to a stable isotope mixing model, CSIA can thus help to discriminate and apportion the source soil contribution from different land-uses.

Figure 2: Connectivity map of the Baldegg Lake catchment.

2. Modelling

The molecular approach is supported by a modified sediment connectivity index (IC) based on the approach by Borselli et al. (2008) and Cavalli et al. (2013) (Fig. 2). Sediment connectivity is defined as the degree of linkage which controls sediment fluxes throughout landscape, and, in particular, between sediment sources and downstream areas and finally the freshwater system (Cavalli et al., 2013). The identification of connectivity patterns allows for an estimation of the contribution of a given part of the catchment as sediment source, and it defines sediment transfer paths.

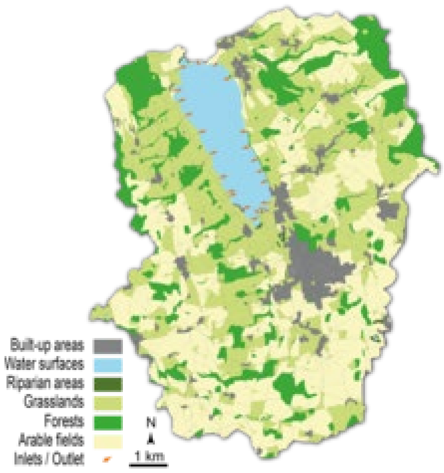

Figure 3: Land-use map of the Baldegg Lake catchment.

3. Study site and sampling

The Baldegg Lake catchment (Canton Lucern, Switzerland) was chosen to apply this combined approach of geochemical fingerprints and sediment connectivity modelling. Almost 80% of the catchment area is used intensively for agriculture, while forests and urban areas cover less than 20% (Fig. 3). The lake is eutrophic since the end of the 19th century, despite several attempts to restore the water quality (including an artificial oxygenation system since 1982). Each land-use geochemical fingerprint is defined from the analysis of plants and soils. The dynamic of sediment input to the freshwater system is assessed on a short- and long-time scale, using (1) river suspended sediments sampled during high flow conditions and (2) a lake sediment core covering the last decades.

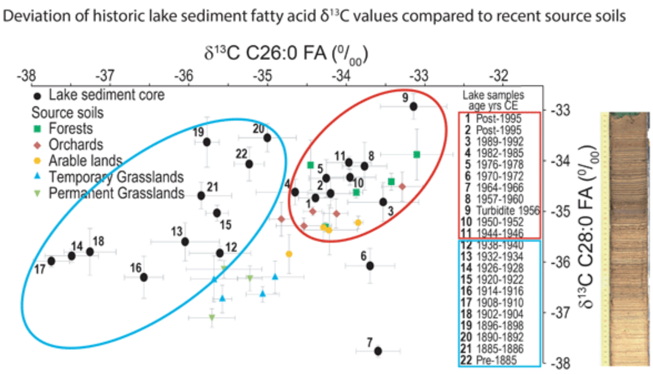

Fig. 4: Isoplot of C26:0 and C28:0 FA from lake sediment core and source soils reveals the discrepancy between source and sink before 1940 (Lavrieux et al, 2019).

5. An unknown source?

After the isotopic characterization of the different landuses in the Baldegg catchment the comparison with the lake sediments (Lavrieux et al., 2019) revealed a big discrepancy between the sediments older than 1940 and the source soils (Fig. 4). They showed more negative values than the soil samples. The only explanation for this observation is an unrecognized source on the land or in the water column. With sampling of the potential candidates reed grass, ponds and peat bogs in the Baldegg catchment we were able to exclude these as origin of the unknown negative source.

In a recent MSc thesis (S. Albiez, 2022) we were able to show the ability of algae from the Lake Baldegg water column, to produce depleted LCFAs. Thus, an algal source of the depleted LCFAs is likely. We will now focus on the possible algal producers and carry on the research at Lake Baldegg.