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Session HS9.2/GM9.8/SSS2.31 - Measuring and modelling fine sediment sources, transit times and redistribution in river catchments

Spatial and temporal changes in apportionments by using sediment fingerprinting in a Spanish Pyrenean river catchment.

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Introduction

Information on sediment contribution and transport dynamics from the contributing catchment to reservoirs is needed to develop management plans for maintaining reservoir sustainability.

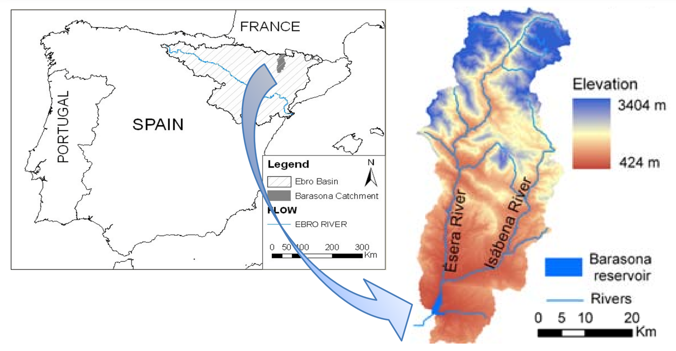
Purpose: investigate how the land use sediment contributions change along the streams and on time to the reservoir following the fingerprinting procedure.

Changes in the land uses over the last few decades in the Pyrenean Region → affecting sediment production

erosion processes greatly affected by vegetation cover

Land use distribution varies from north to south:
- forests predominating in the highlands
- cultivated land in the more gentle southern areas

Study area



Barasona reservoir catchment
Central Spanish Pyrenees (1509 km^2)

Climate: mountain type, wet and cold.
Precipitation and temperature gradients
- from 500 mm and 12ºC at the reservoir
- to > 2000 mm and < 4ºC above 2000 m

Rugged **topography**
- Altitudinal range of 3000 m
- Average catchment slope: 39 %

Hydrologic regime: transitional nivo - pluvial

Drainage network: Ésera River, Isábena River

Floods are caused by:
- late spring–early summer snow melt and summer thunderstorms
- late autumn heavy rains.

Rivers flow through blocky or rocky channels → erodible channel banks are very local


692 ha

Siltation problems since its construction
(Valero-Garcés et al. 1999; Navas et al. 2009)

Bathymetric survey in the reservoir (period 1932-1996) → **350 t/km^2 year**
Avendaño-Salas et al. (1997)

Previous studies → Main sediment sources:
- 1º badlands and bare soils
  - < 1 % of the catchment
  - Eocene marls
- 2º agricultural uses

(Palazón and Navas, 2014)

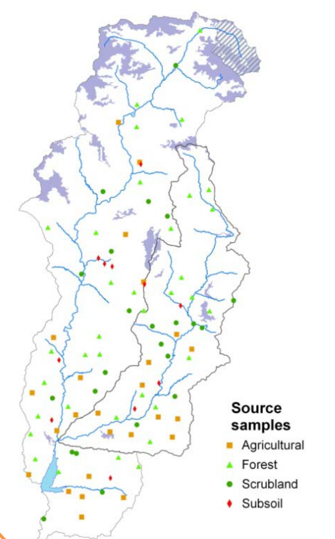
Material and Methods

Sample collection:

Designed to assess how the intense changes in land uses occurred in the region affected the sediment production of the drainage catchment

Source samples:

Distribution: non-aligned random spatial sampling method
(spsample function, sp library, R)



Excluded areas → *Rock*
- slope > 30%
- altitude > 2000 m a.s.l.

96 composite samples to characterize the signatures of potential sediment source

- 0-5 cm depth → high stoniness and surface soil roughness
- 4 samples → composite sample

Four categories

- agricultural uses

- forests

- scrubland

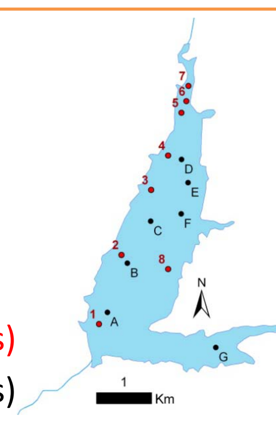
- badlands and subsoils

Sediment samples:

Surface reservoir sediments:

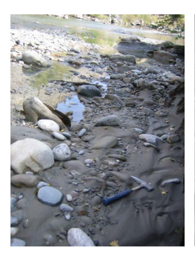
Exposed deposits representative of the most recent and accessible reservoir filling

Composite samples spaced two decades:
- 1995 (8 samples)
- 2011 (7 samples)



Barasona reservoir

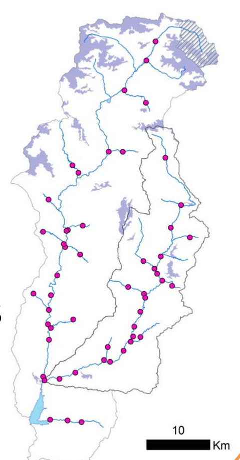
Channel bed sediments:




Exposed deposits from main rivers and tributaries

Limited to clearly identifiable depositional zones with substantial amounts of fine-grained sediments

Transects (50 m) x 6 samples → 53 composite samples



Intermediate mixtures → represent material delivered from the upstream catchment to the reservoir

Fingerprinting procedure:

A.- Exclusion of non-conservative fingerprint properties for the analysis:

- Range test: concentrations in tracer properties in reservoir sediments falling outside the range in source values. → excluded

Fingerprint properties	n
environmental radionuclides	6
elemental composition	25
magnetic susceptibility	1
Total	32

analyzed in the < 63 µm fraction

B.- Statistical analysis of differences to identify a subset of tracer properties that discriminate the sources

Kruskal Wallis H-test + Discriminant Function Analysis (minimization of Wilk´s lambda)

↓

Optimum composite fingerprint: ^{40}K, ^{137}Cs, Li, Sr, Ti

C.- Estimation of source contributions from each mixture assuming a conservative mass balance

$$\sum_{j=1}^{m} a_{i,j} \cdot x_j = b_i \quad \begin{cases} \sum_{j=1}^{m} x_j = 1 \\ 0 \le x_j \le 1 \end{cases}$$

$a_{i,j}$ fingerprint i in source type j (j=1 to m)
x_j contribution of source j
b_i fingerprint i (i=1 to n) in the sediment

Here, a Monte Carlo global sampling routine as optimization method

Written in **C programming language**

Designed to: (Palazón et al. 2015)
- generate and test **uniformly distributed solutions**
- **multiple** unmixing samples evaluation
- **reproducibility analysis**→ user-defined “seed”
- deliver an **optimal solution** and its **dispersion**

10^6 generated solutions were assessed and ranked by:

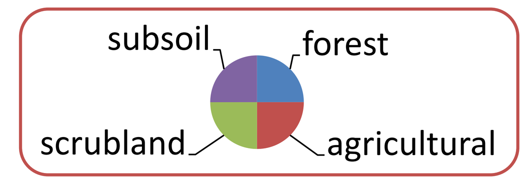
$$GOF = 1 - \frac{1}{p} \times \sum_{i=1}^{n} \left\{ \left(\frac{\left| b_i - \sum_{j=1}^{m} x_j a_{i,j} \right|}{\Delta_i} \right)^2 \right\}$$

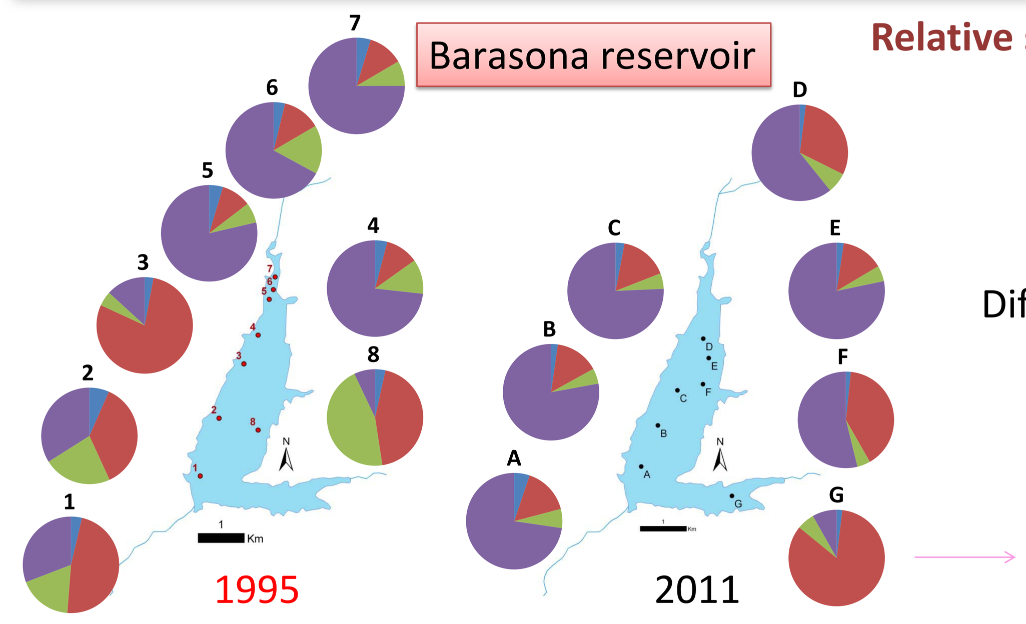
based on Collins et al. (1997)

100 best options: **Optimal solution**

Results

Relative source contributions:

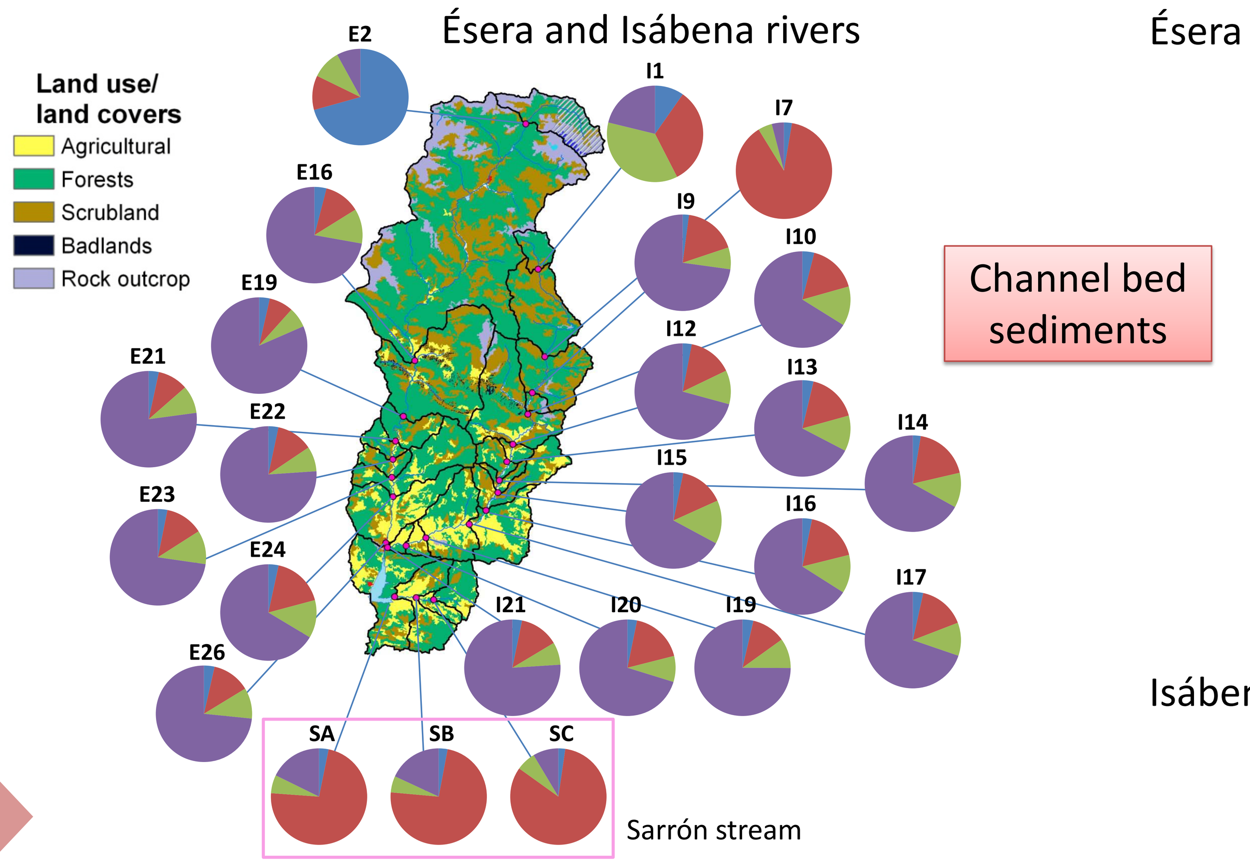


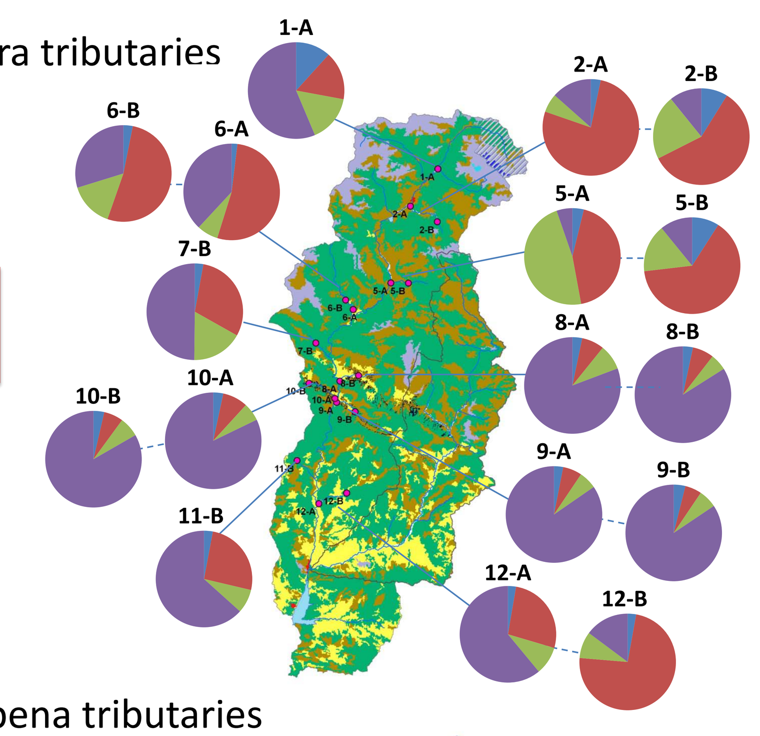


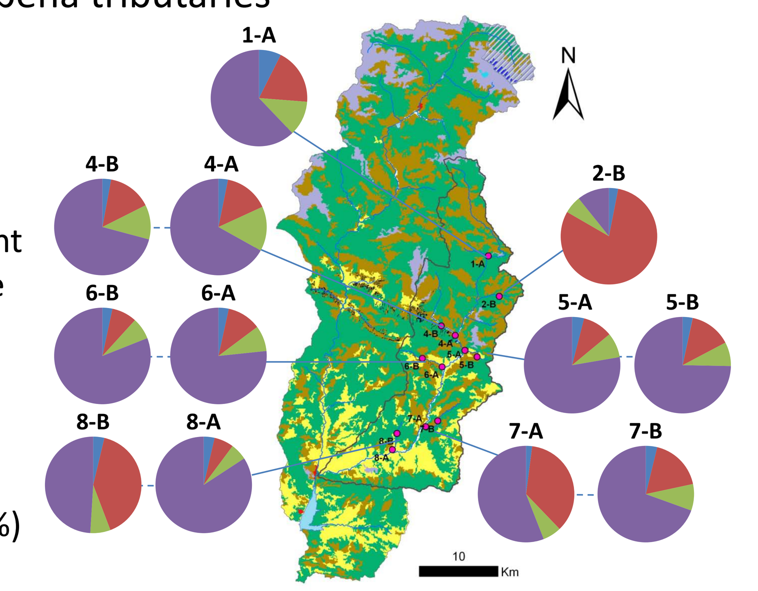
Differences between the two time-spanning samples reveal that agricultural fields contributed more in the 90s

→ Contributions from Sarrón stream

Channel bed sediments







- Main rivers:

Subsoil source (badlands included) contributions are limited in the catchment headwater which turn to be greater than 70 % for river reaches closer to the reservoir.

Source contributions for Sarrón stream are in relation to the distribution of the land uses within its contributing catchment .

- Tributaries:

Subsoil source (badlands included) are also main source of sediments (> 50%) for the southern tributaries.

Conclusions

- The fingerprinting procedure provided information about the relative contributions from land use sources to the different surface sediments.
- Differences in agricultural source contributions between sampling periods could be related with changes in agricultural management practices.
- The presence of the badlands and the greater percentage of bare soils in the southern part of the catchment done that the subsoil source become principal in the downstream sediment samples.
- The spatial distribution of source contributions for channel bed sediments are in agreement with source contributions obtained for the reservoir filling.
- Assessing contributions along the main rivers and tributaries enabled us to achieve a more general view of the erosion processes taking place in the Barasona river catchment.
- Study fine sediment characteristics and their contributions in river catchments provide unique and diverse information to address catchment management problems, improving the spatial and temporal knowledge of land use sediment source contributions along the catchment to the reservoir infill.

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