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From the hillslope to the river: multi-scale sediment transfers monitoring in the Beaujolais vineyard (France)



Jessica PIC, Mathieu FRESSARD, Nadia CARLUER, Étienne COSSART

25th of July 2024



1 – Conceptual framework

1

Complexity of hydro-sediment transfers in an agricultural context

- High erosion rates



Surface runoff in a vine plot, village of Saint-Lager



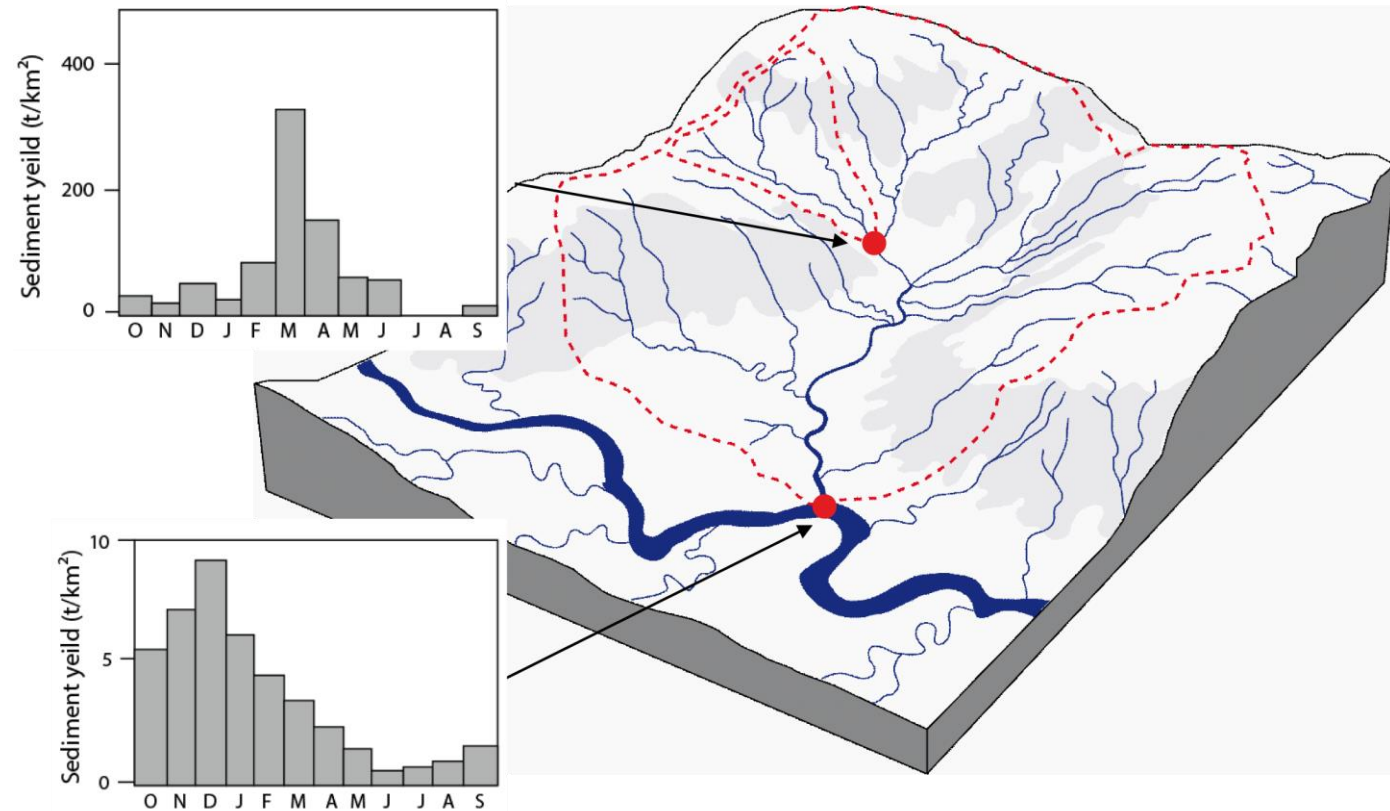
Turbid flooding in a street in the village of Odenas, September 12th, 2023
Source : Photo Progrès/Daniel DUFOUR ; <https://www.leprogres.fr/faits-divers-justice/2023/09/12/a-odenas-le-ruisseau-sort-de-son-lit-et-provoque-une-inondation>

1 – Conceptual framework

Complexity of hydro-sediment transfers in an agricultural context

- High erosion rates
- Non-linearity in the response of catchments

Spatial and temporal paradoxes of sedimentary signals (from McGuinness et al., 1971, modified by Cossart et al., 2017)



1 – Conceptual framework

2

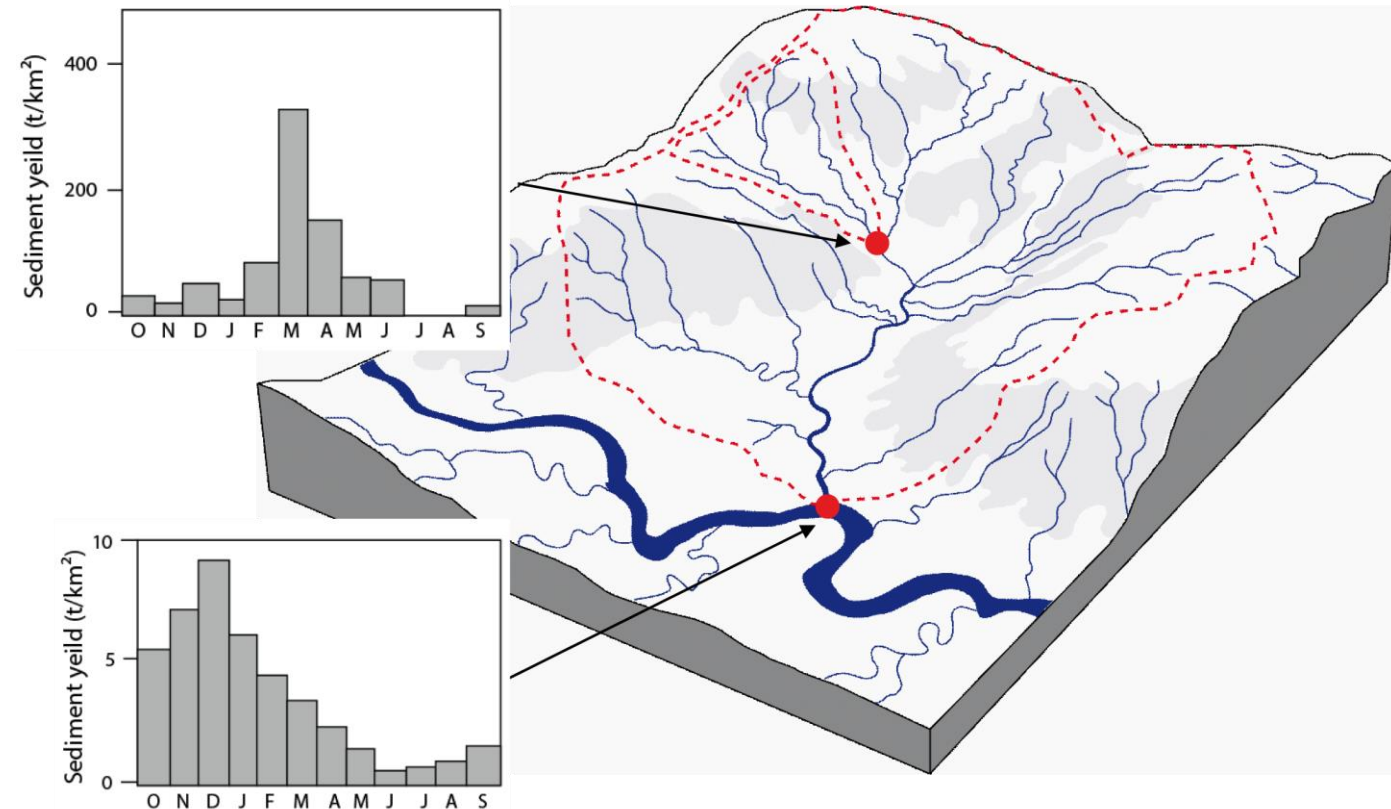
Complexity of hydro-sediment transfers in an agricultural context

- High erosion rates
- Non-linearity in the response of catchments
- Landscape structure and sediment cascade

MULTISCALE MONITORING OF SEDIMENT TRANSFERS

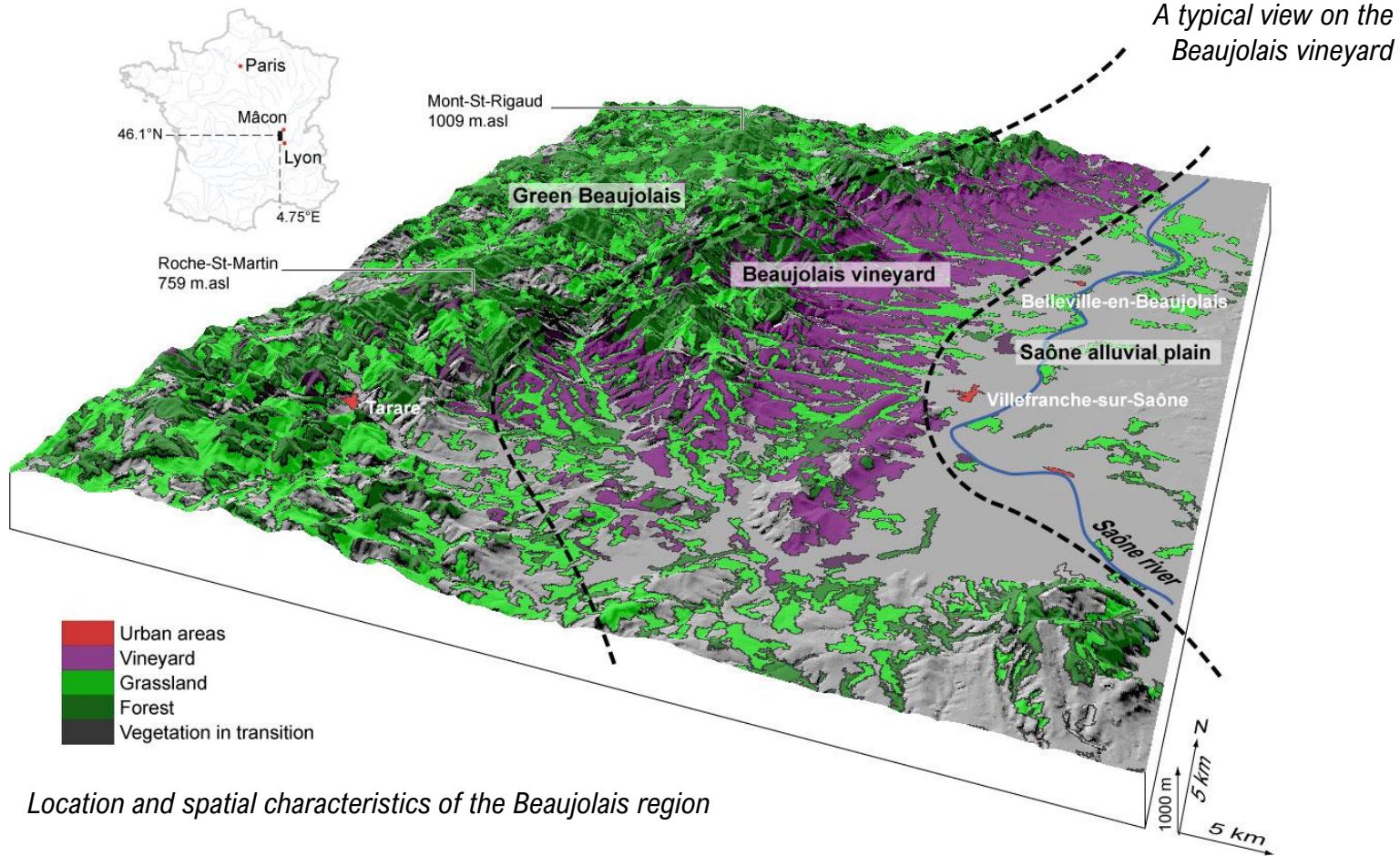
- Field metrology
- Spatial and temporal dynamics
- Process relays
- Connectivity relationships

Spatial and temporal paradoxes of sedimentary signals (from McGuinness et al., 1971, modified by Cossart et al., 2017)



2 – Study area

The Beaujolais vineyard: monoculture on steep slopes



Location and spatial characteristics of the Beaujolais region

A typical view on the Beaujolais vineyard

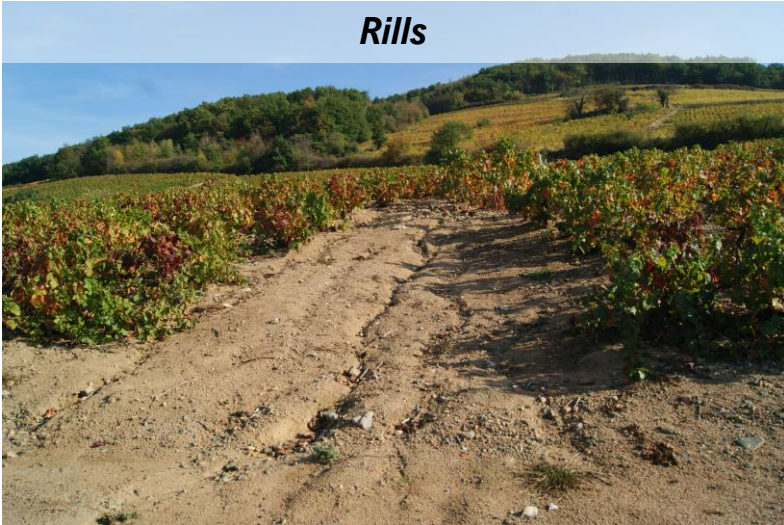


Aerial photograph of a group of vineyard plots (IGN, April 2017)

2 – Study area

The Beaujolais vineyard: visible forms of soil erosion

Rills



Ditch erosion



Sediment deposit within the river



Sediment deposit on a road



Inter-row rills



Sediment deposit within a ditch



2 – Study area

The Beaujolais vineyard: infrastructures intercepting sediment transfers



Spatial pattern of sediment transfer within a densely structured landscape

Soil bund along a grassed track



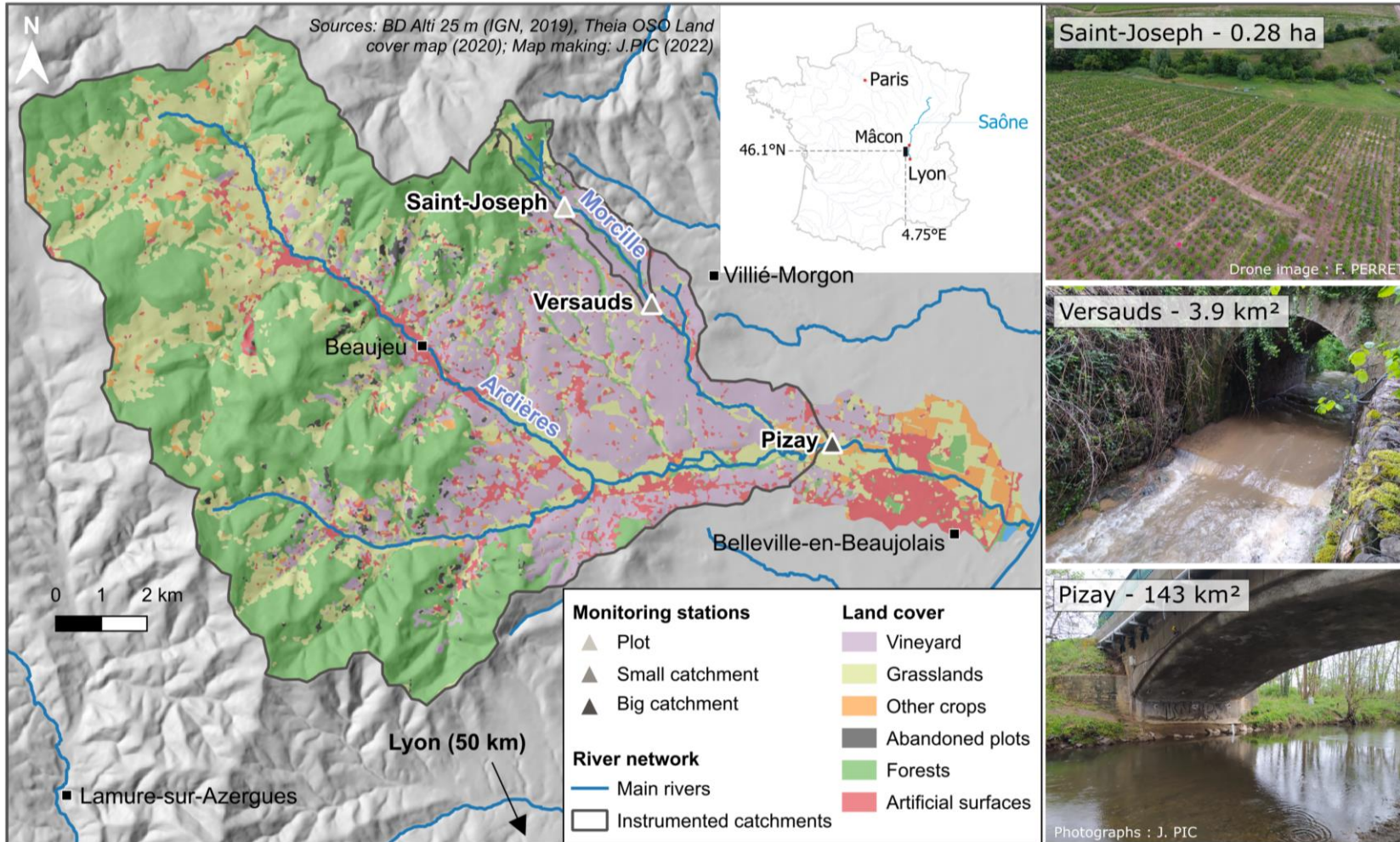
Mid-plot gutter



Emptied sediment trap

© N.CARLUER

3 – Material and methods

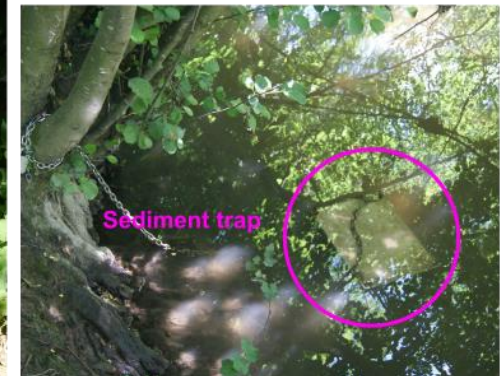


Monitoring network at different scales

- 3 stations at 3 scales
- Traditional hydrological monitoring
- 2 hydrological years, relatively dried years

3 – Material and methods

Monitoring sediment transfers in the river



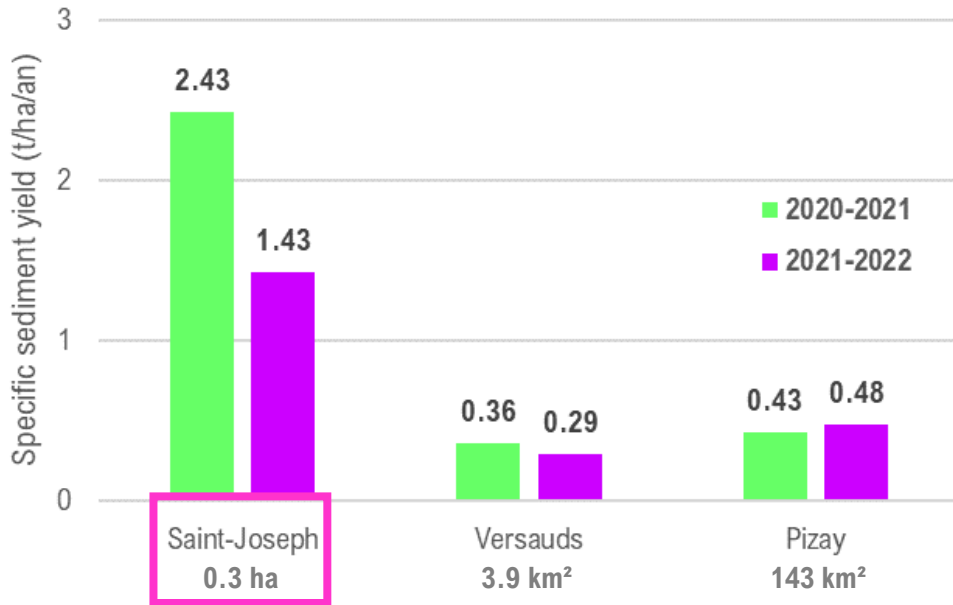
3 – Material and methods

Monitoring sediment production at the plot-scale



Annual sediment budget

Specific sediment yields by station

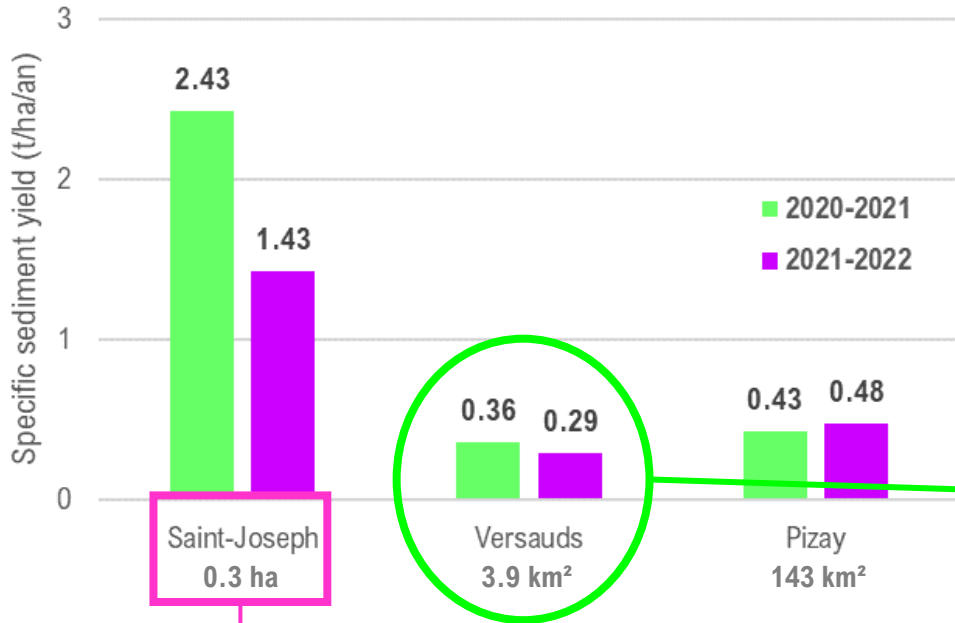


- Trap: 60 % of transfers
- Suspended solids: 40 %

4 – Results

Annual sediment budget

Specific sediment yields by station



- Trap: 60 % of transfers
- Suspended solids: 40 %

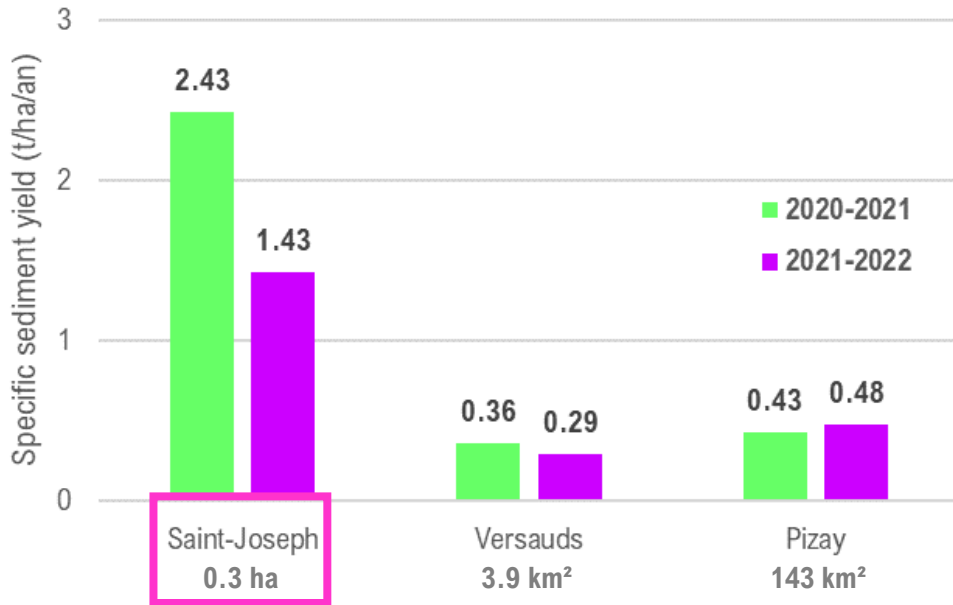


SAND PROBLEM



Annual sediment budget

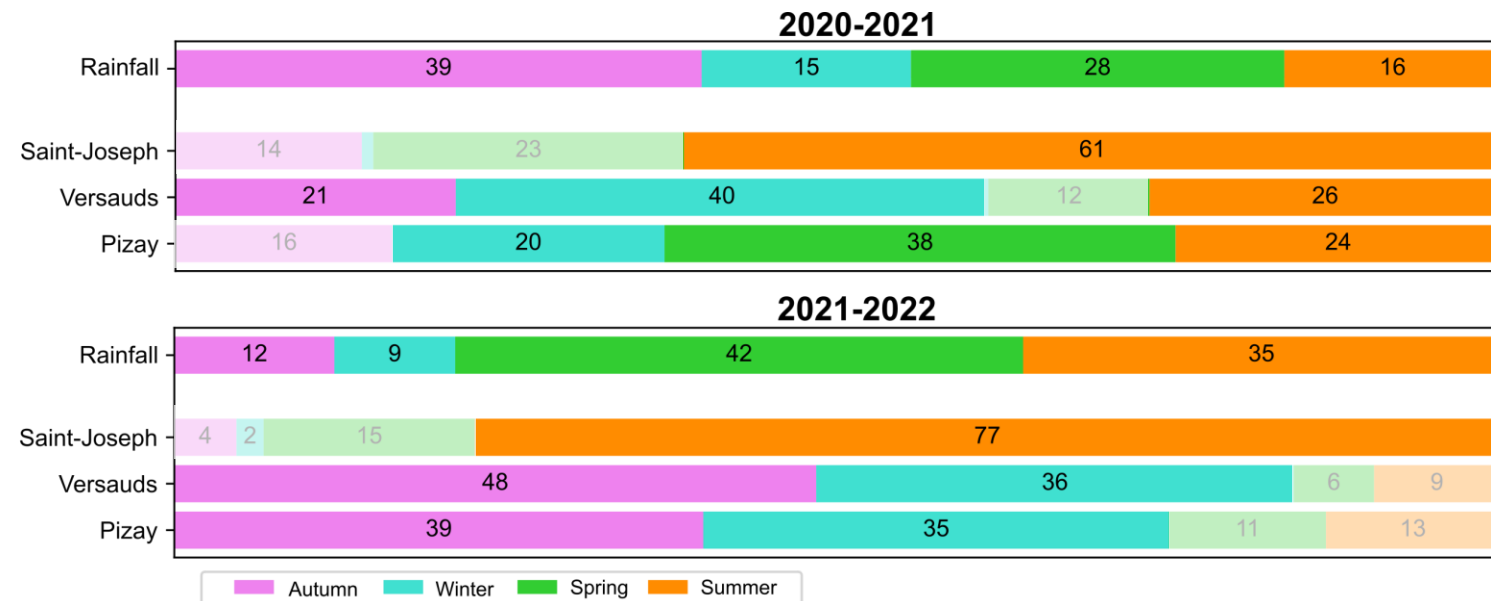
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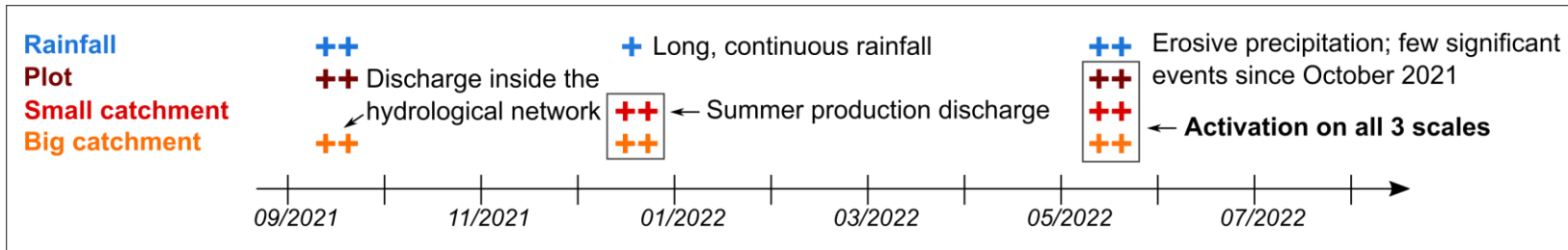
Seasonal phase shift plot – river

- Summer sediment transfers at the plot-scale
- More balanced and variable seasonal rhythms in rivers

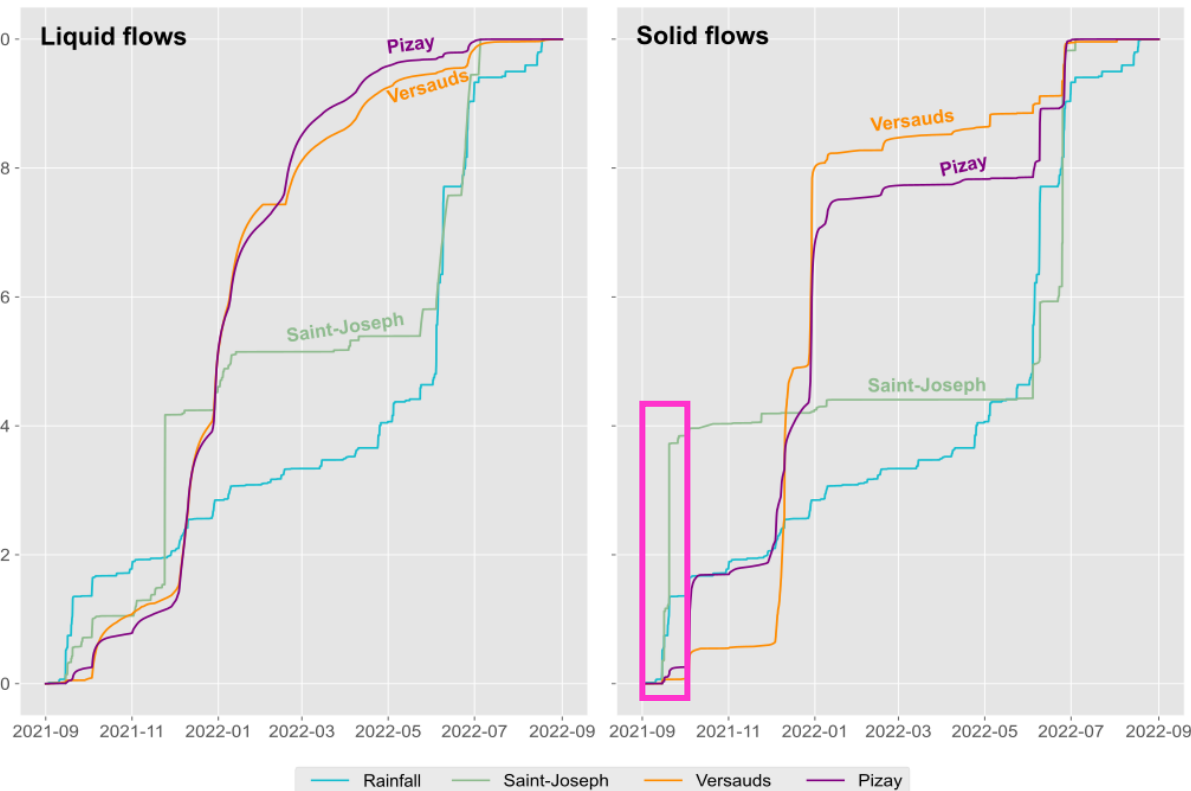


Share of annual sediment transfer (%) at the three stations for the hydrological years 2020-2021 and 2021-2022.

4 – Results



Overview of sediment dynamics observed at the 3 scales during the 2021-2022 hydrological year

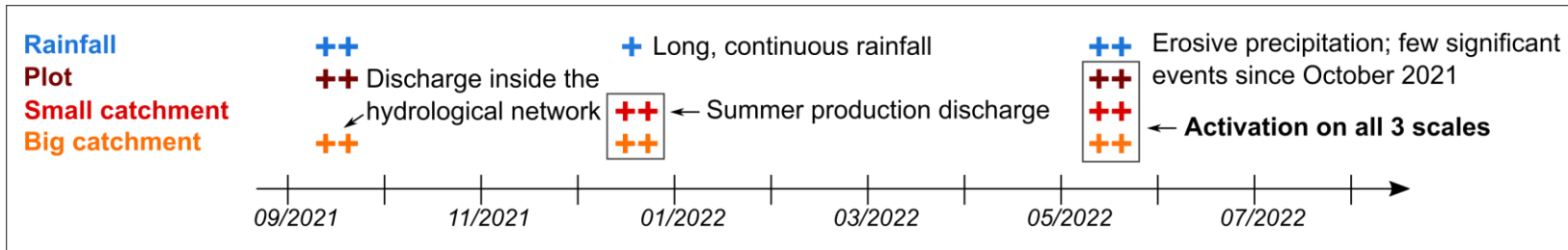


2021-2022: Desynchronisation of solid flows and rainfall in the river

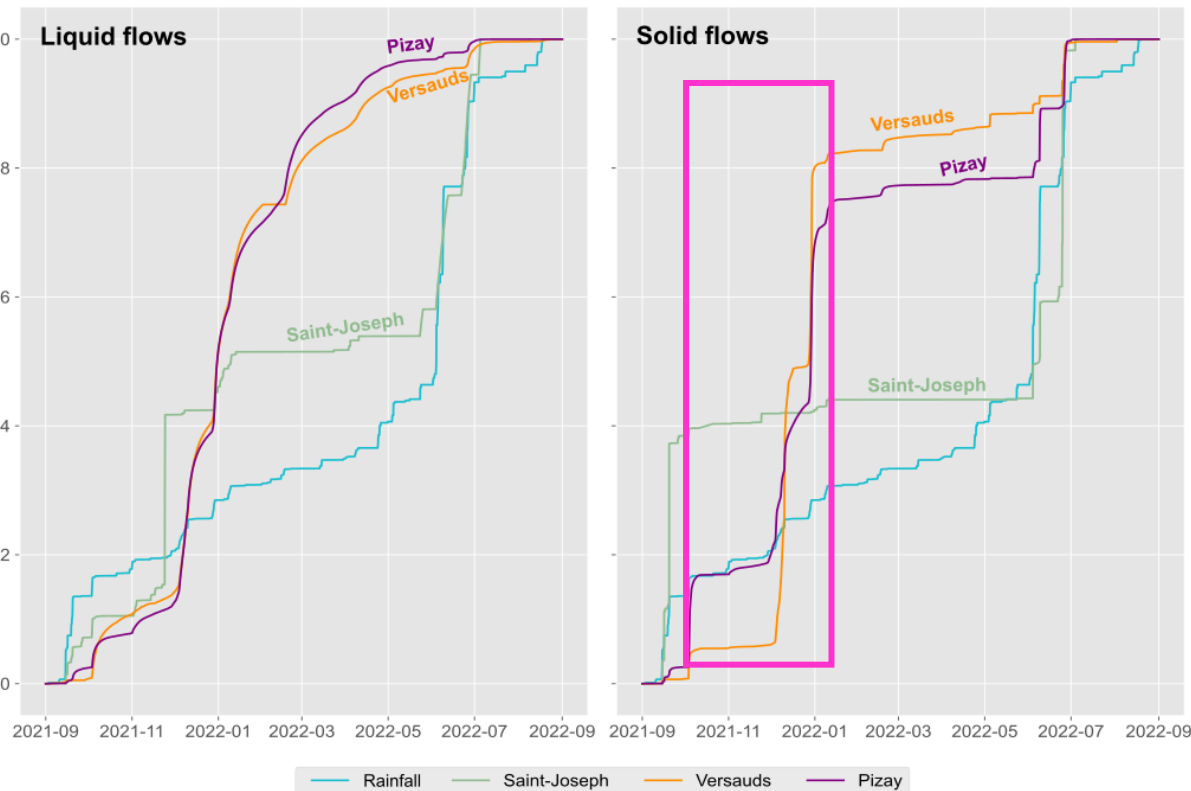
- **Summer 2021:** erosive precipitation and sediment production

Cumulative liquid and solid flow curves, 2021-2022 hydrological year

4 – Results



Overview of sediment dynamics observed at the 3 scales during the 2021-2022 hydrological year

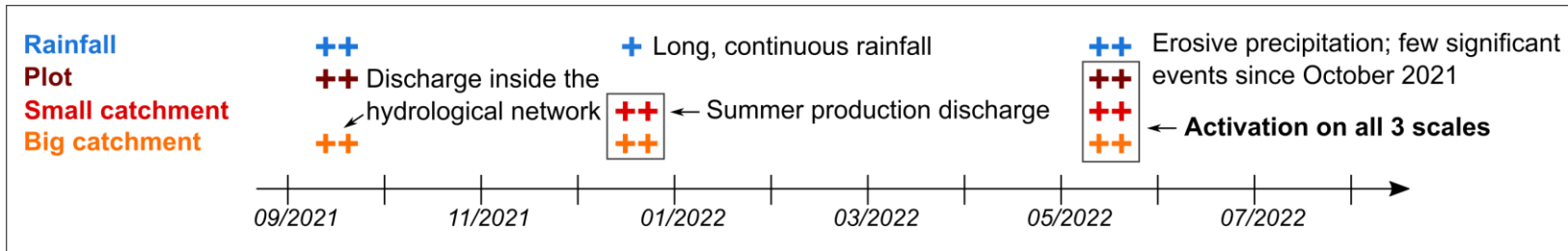


2021-2022: Desynchronisation of solid flows and rainfall in the river

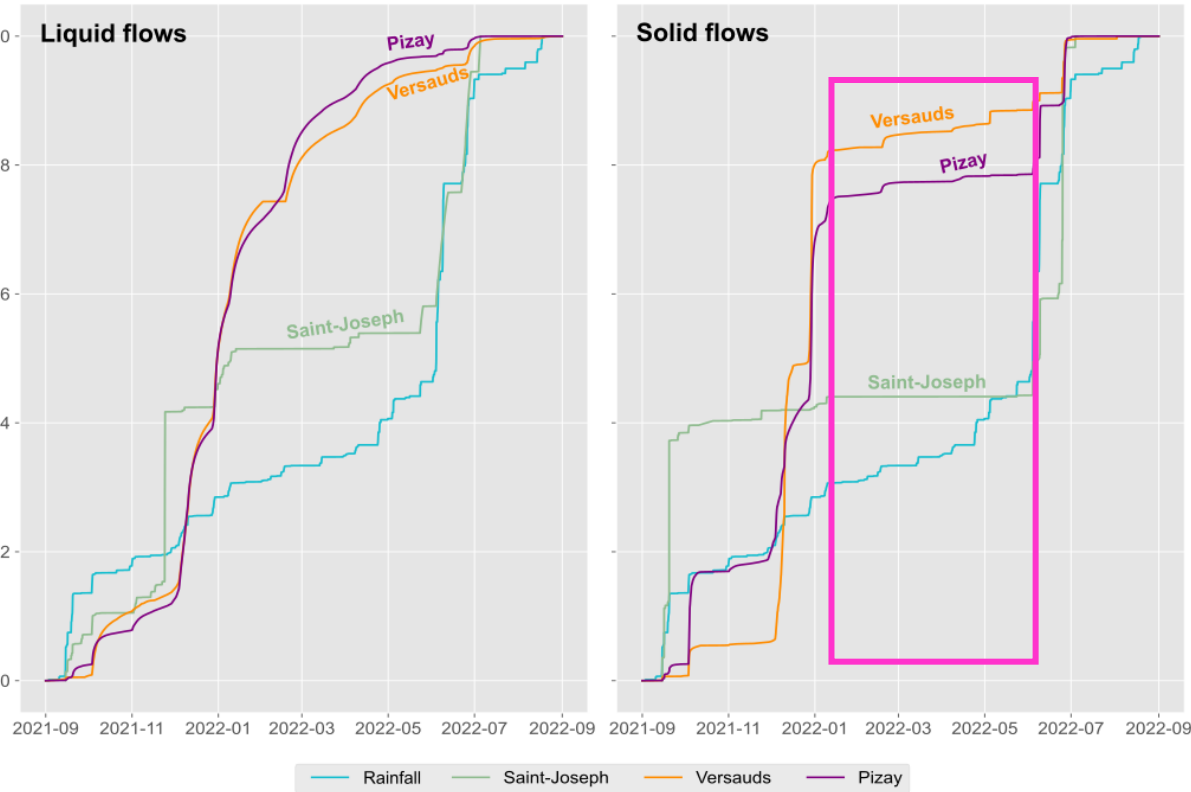
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- **Autumn-winter 2021 :** sediment discharge

Cumulative liquid and solid flow curves, 2021-2022 hydrological year

4 – Results



Overview of sediment dynamics observed at the 3 scales during the 2021-2022 hydrological year

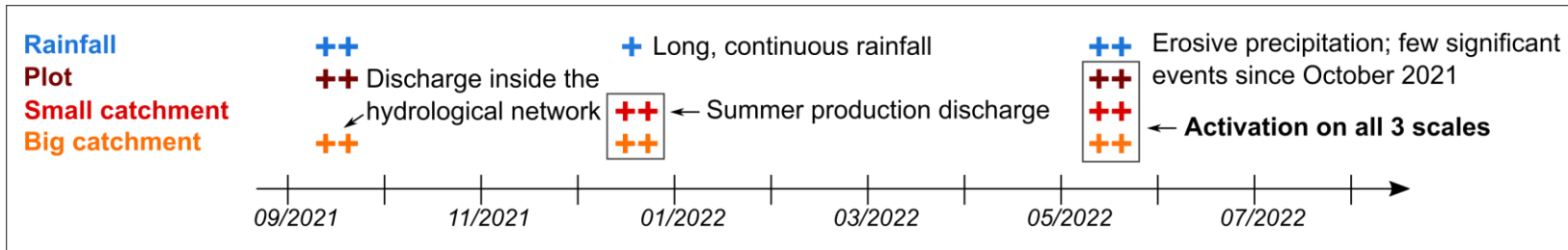


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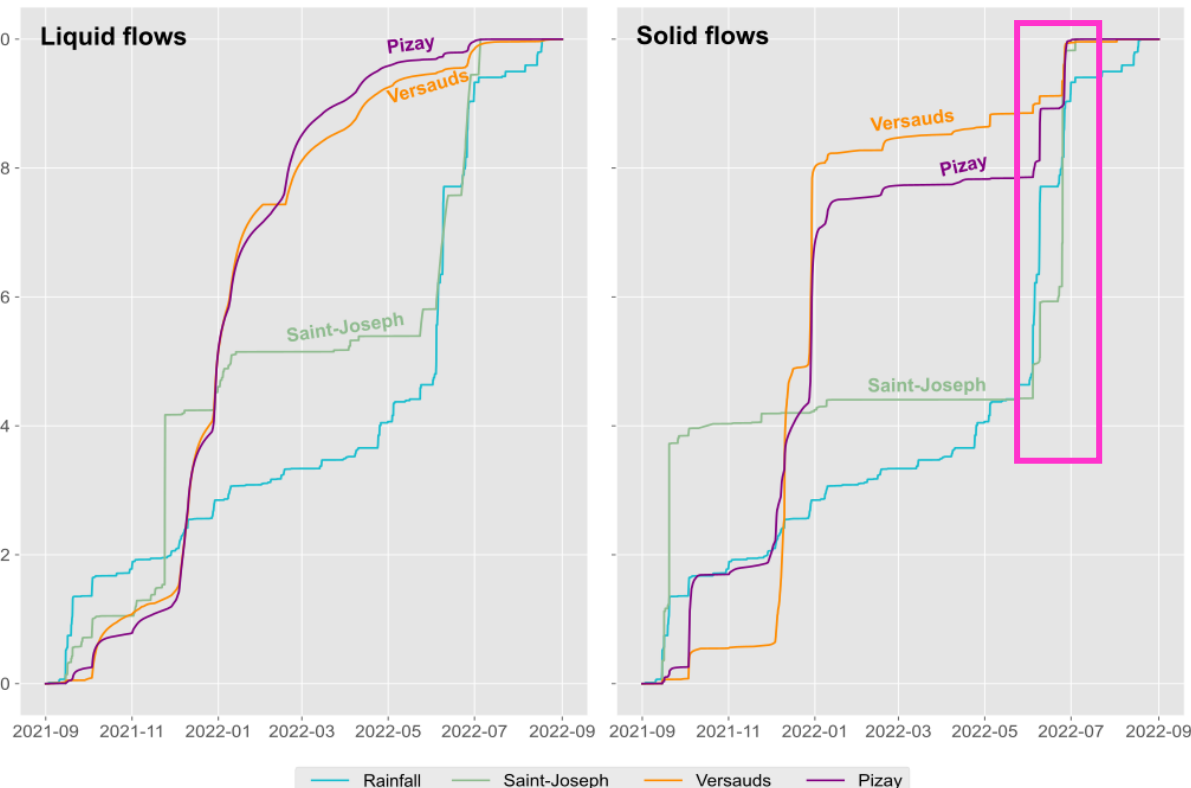
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- **Autumn-winter 2021 :** sediment discharge then drying up of sediment stocks

Cumulative liquid and solid flow curves, 2021-2022 hydrological year

4 – Results



Overview of sediment dynamics observed at the 3 scales during the 2021-2022 hydrological year

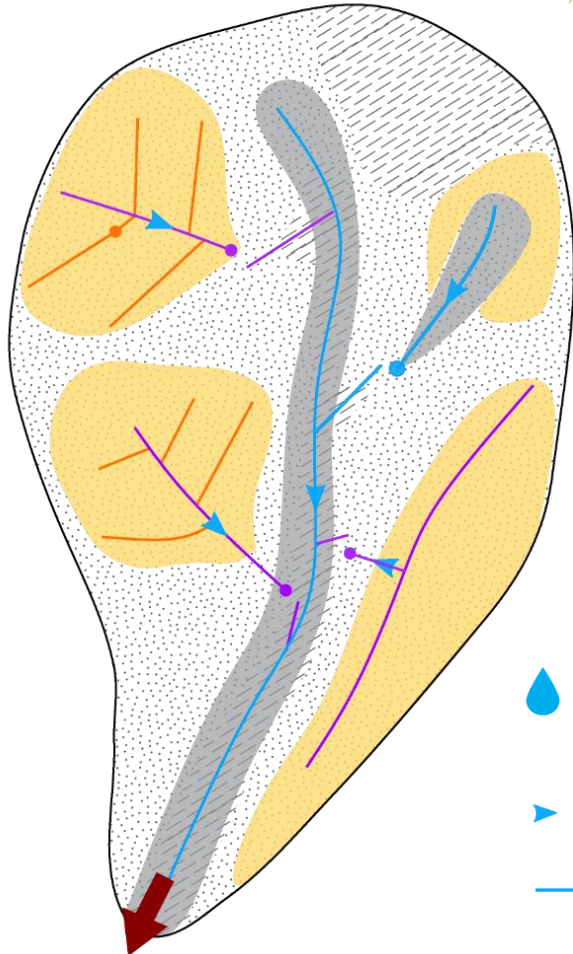


2021-2022: Desynchronisation of solid flows and rainfall in the river

- **Summer 2021:** erosive precipitation and sediment production
- **Autumn-winter 2021 :** sediment discharge then drying up of sediment stocks
- **Spring-summer 2022:** activation on all three scales

Cumulative liquid and solid flow curves, 2021-2022 hydrological year


Floods linked to erosive precipitation





Flood types


- Jerky sediment transfers


Flood type	Rainfall	Liquid flow	Suspended solids concentration	Characteristics
Floods linked to erosive precipitation	++	+	++	Sediment production on hillslopes Total clean-up of channel sediments Possible complete activation of the sediment cascade if succession of events


 Rainfall
 Intensity = size
 Duration = number


 Sediment production (soil erosion)


 Vineyard


 Other landcover (forest, grassland, etc.)


 Sediment transfers


 Longitudinal man-made infrastructures


 Flow direction

 Transfer intensity

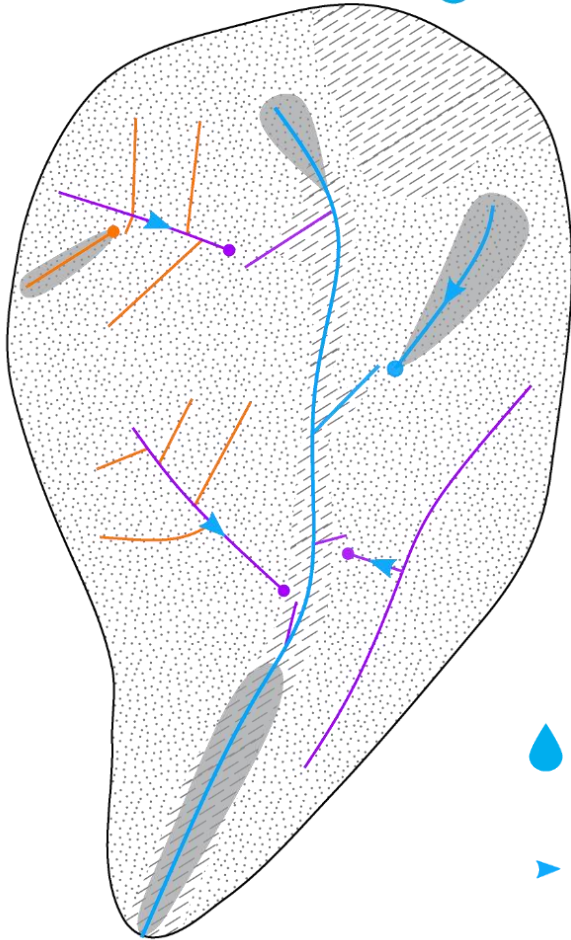
 Transverse man-made infrastructures

 Hydrographic network

 Connected

 Disconnected

Small floods

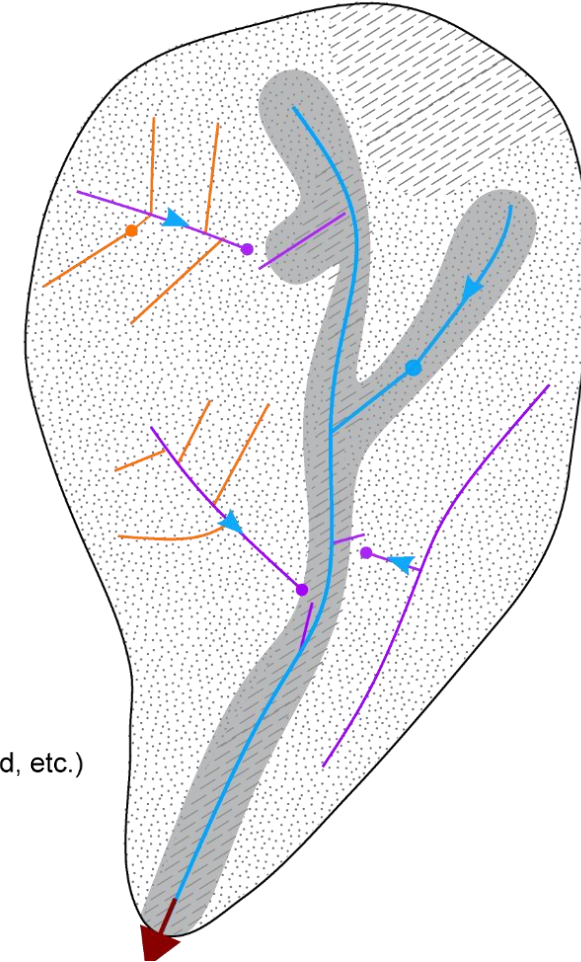



Flood types


- Jerky sediment transfers


Flood type	Rainfall	Liquid flow	Suspended solids concentration	Characteristics
Floods linked to erosive precipitation	++	+	++	Sediment production on hillslopes Total clean-up of channel sediments Possible complete activation of the sediment cascade if succession of events
Small floods	-	+	-	Low sediment transfer
Intermediate floods	+	+	+	Drainage of channel sediments


Intermediate floods





 Rainfall
 Intensity = size
 Duration = number


 Sediment production (soil erosion)


 Sediment transfers


 Flow direction


 Transfer intensity


 Hydrographic network


 Vineyard

 Other landcover (forest, grassland, etc.)

 Longitudinal man-made infrastructures

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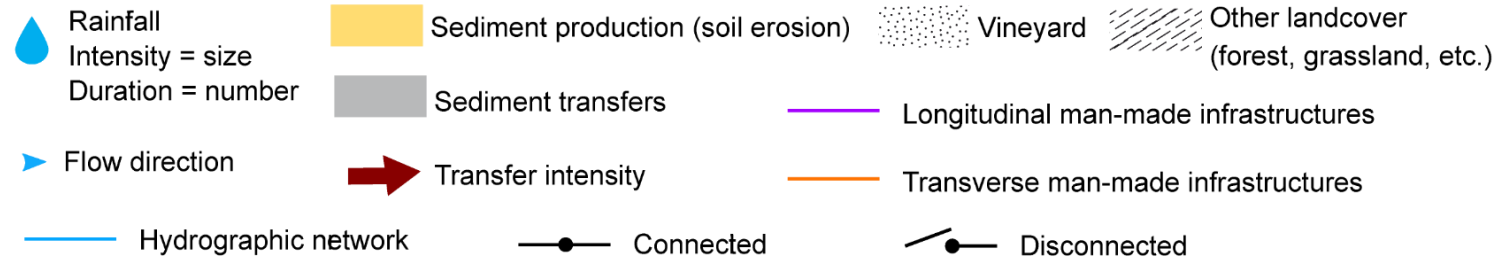
 Connected

 Disconnected

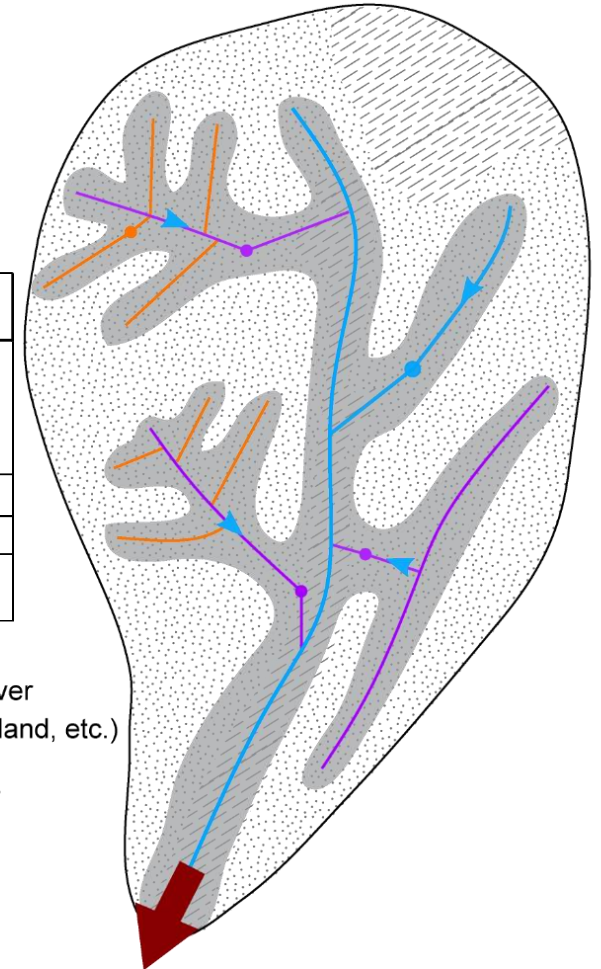
Flood types

- Jerky sediment transfers

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Small floods	-	+	-	Low sediment transfer
Intermediate floods	+	+	+	Drainage of channel sediments
High flow floods	++	++	+	Complex signals Complete activation of the sediment cascade

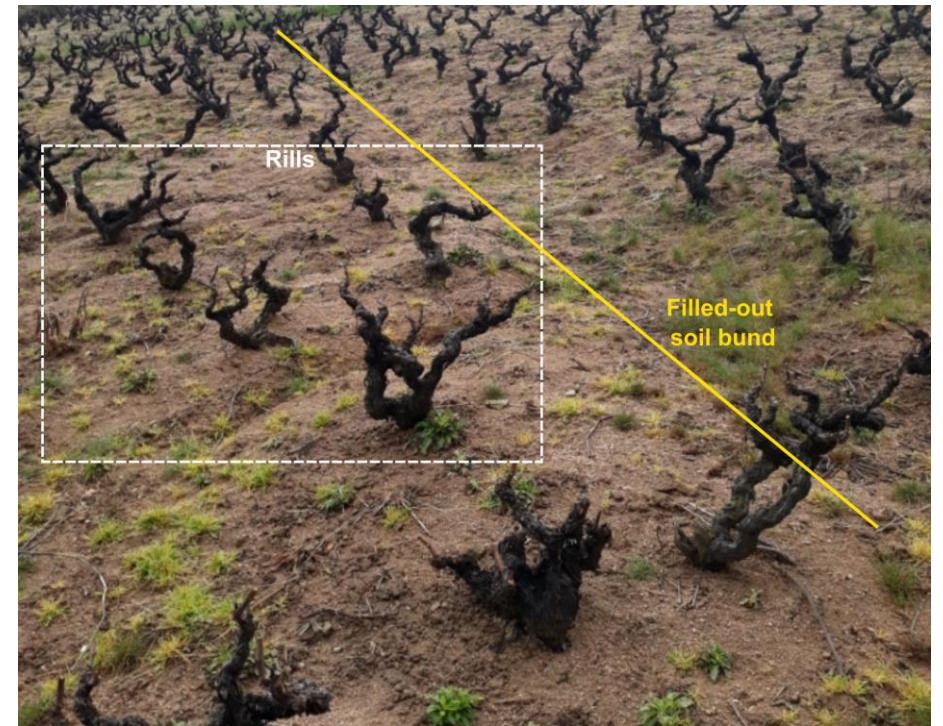


High flow floods ▶▶▶



Subtle influence of the landscape structure on the sediment transfers

- The plot management seems to reduce sediment production



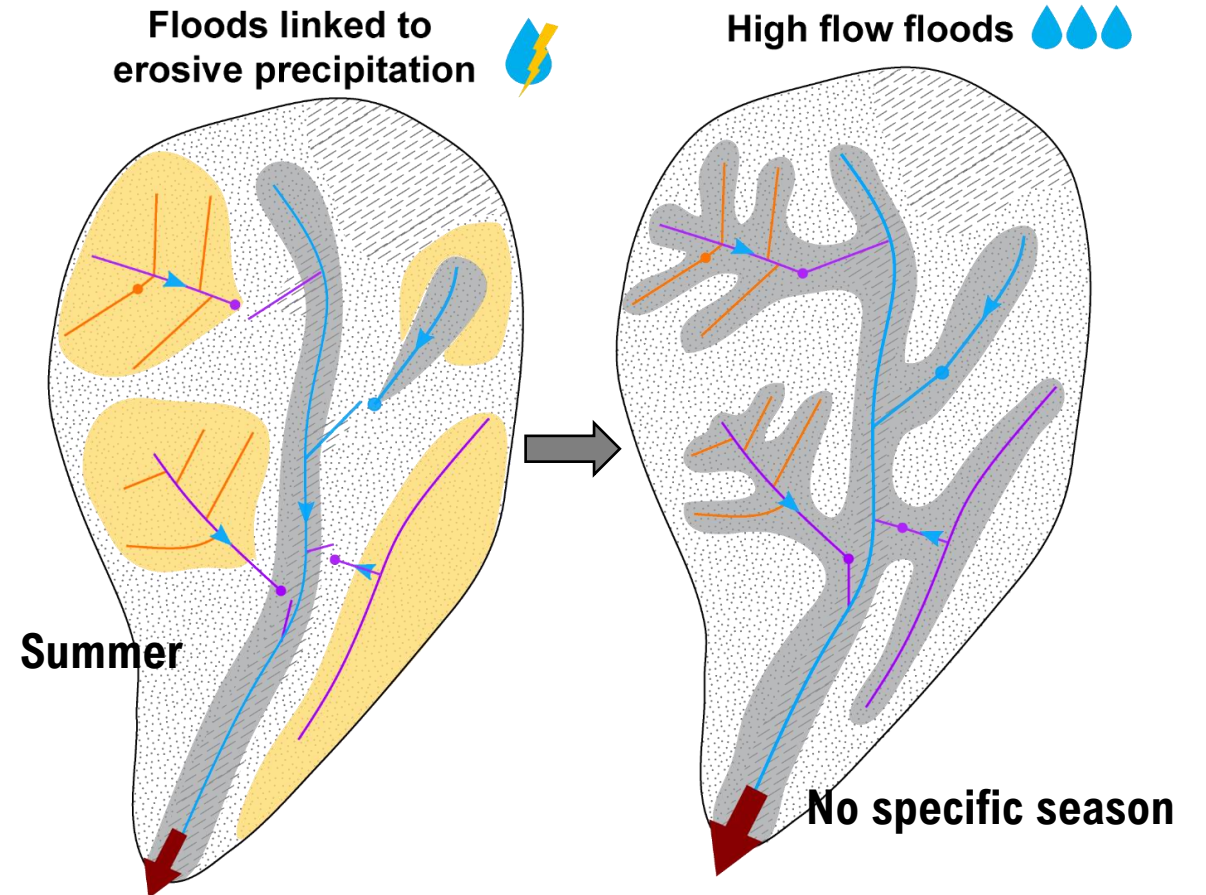
Plot with filled-out soil bunds and rills

Subtle influence of the landscape structure on the sediment transfers

- An anthropogenic drainage network facilitating or reducing the sediment transfers at the catchment-scale ?



Sediment transfers and sediment storage within a ditch



Subtle influence of the landscape structure on the sediment transfers

- Monitoring at the infrastructure- and event-scale is needed!

Soil bund
Limitation of the transfers
Erosive rainfall



Grassed ditch
Transfers facilitation but
sediment storage



Sediment trap
Sediment storage
Cleaning frequency



© N.CARLUER

River
Sediment storage within the channel
Transfers = high flow floods



- Jerky sediment transfers: summer sediment production then transfers to the river and gradual evacuation
- Limited sediment production but transfers equivalent to estimates (RUSLE)
- Flood type = rare complete activation of the geomorphic system
- Incoming data until September 2024!
- Important link to the landscape structure to understand the sediment transfers
 - Density of drainage infrastructure
 - Distortion of the sedimentary cascade
 - Fragmentation of slopes by networks
 - Dominance of direct connections to the river
 - Different management strategies for upper and lower slopes

5 – Conclusion

- Jerky sediment transfers: summer sediment production then transfers to the river and gradual evacuation
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