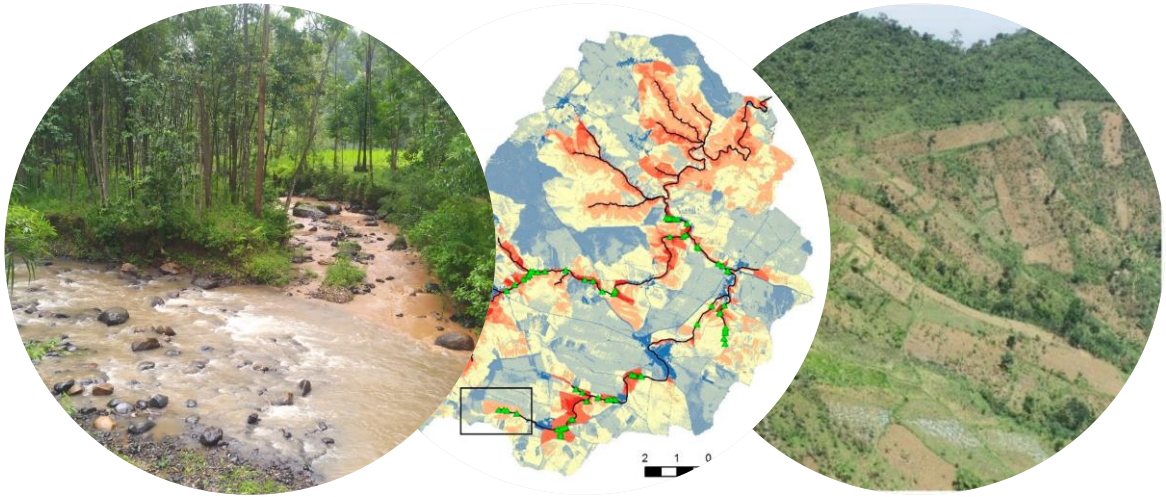
Modelling the dynamics of sediment and associated substances across temporal and spatial scales

TERENO-OZCAR Conference - Jantiene Baartman – 27 September 2023



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Soils and sediment dynamics

- BSc & MSc Soil Science & Geomorphology
- PhD ‘Mind the gap: modelling event-based and millennial-scale landscape dynamics’
- Assistant professor
    - Soil physics and land management group
    - Soil erosion
    - Land degradation & mitigation
    - Numerical modelling

ISRIC Soil Museum, Wageningen

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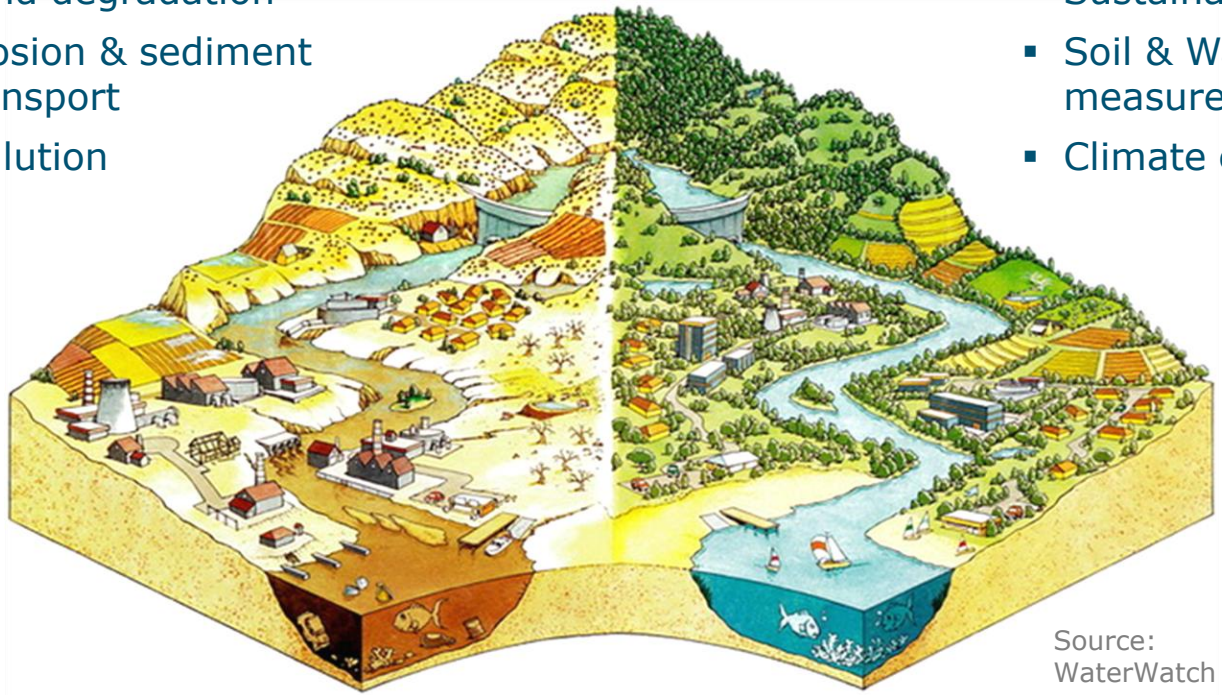
Outline

- Background: sediment dynamics & landscape resilience
- Modelling soil erosion and sediment dynamics
    - Detailed: OpenLISEM
    - Long-term: LAPSUS
    - Index of Connectivity
- Outlook – future work

Sediment dynamics & landscape resilience

- Land degradation
- Erosion & sediment transport
- Pollution



- Sustainable soil management
- Soil & Water Conservation measures
- Climate extremes

Source:
WaterWatch Queensland

Relevance

- Soil erosion remains the most widespread soil threat (FAO, 2019)

- Hydroclimatic extremes, environmental hazards:
  - Floods & droughts
  - Wildfires
  - Pollution (pesticides, plastics)


Erosion south-Limburg (photo: JB)


Uganda (Opedes et al., 2023)


Uganda (photo: HO)

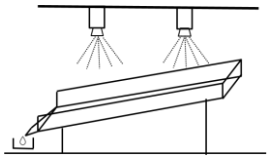

Landfill Rwanda (photo: JB)

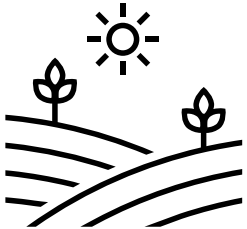

Pluvial flooding July


Girona-Garcia & Vieira, 2021 EGU Blogpost

Research approach

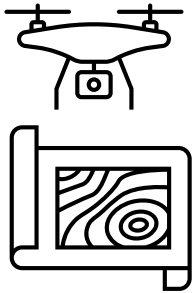
Rainfall simulation experiments: Pesticides, MPs





Field investigations: SWC, Runoff, Sediment

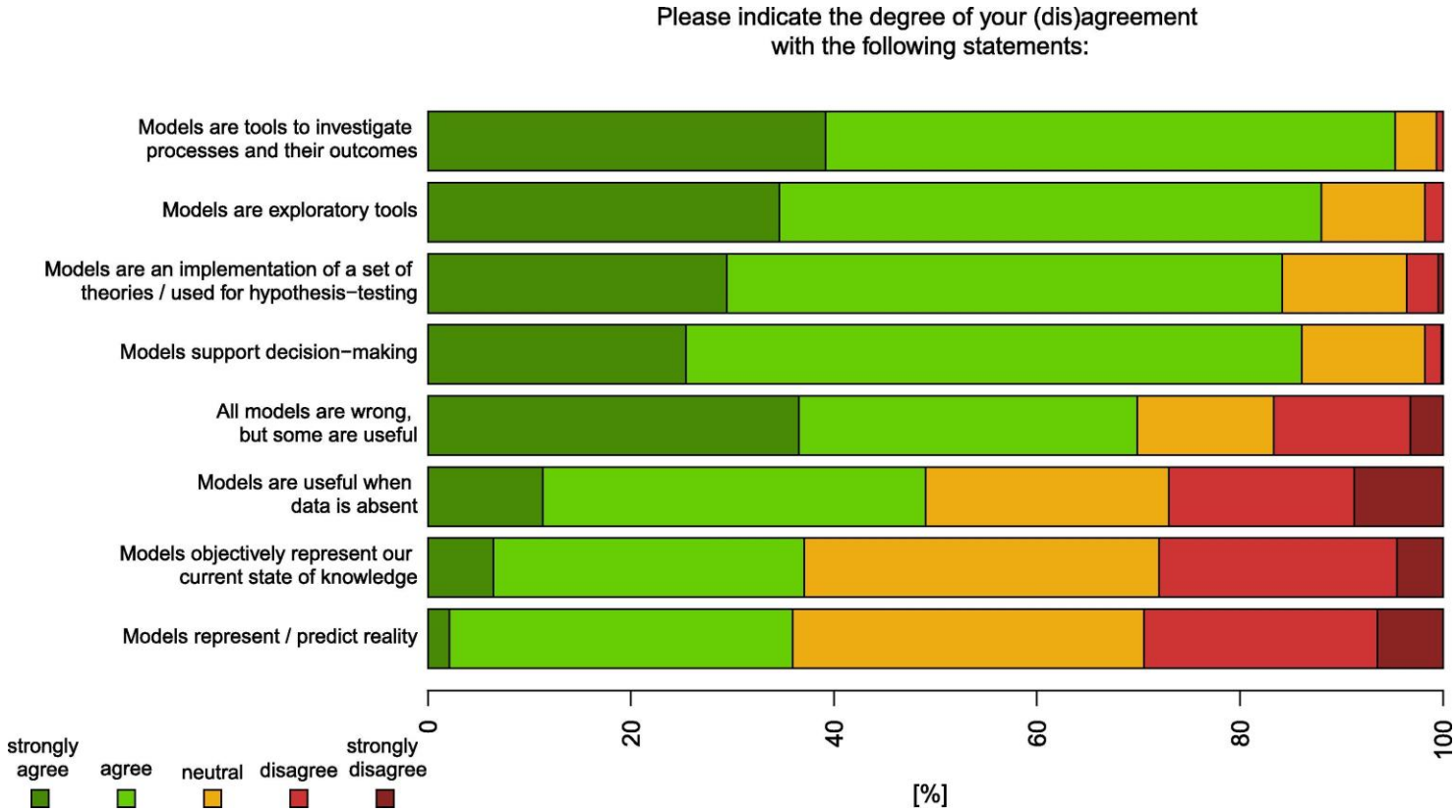
(high resolution) mapping: SWC measures connectivity



Process-based, dynamic modelling: OpenLISEM, PESERA, LAPSUS

Modelling in geosciences

'On the complexity of model complexity: Viewpoints across the geosciences'



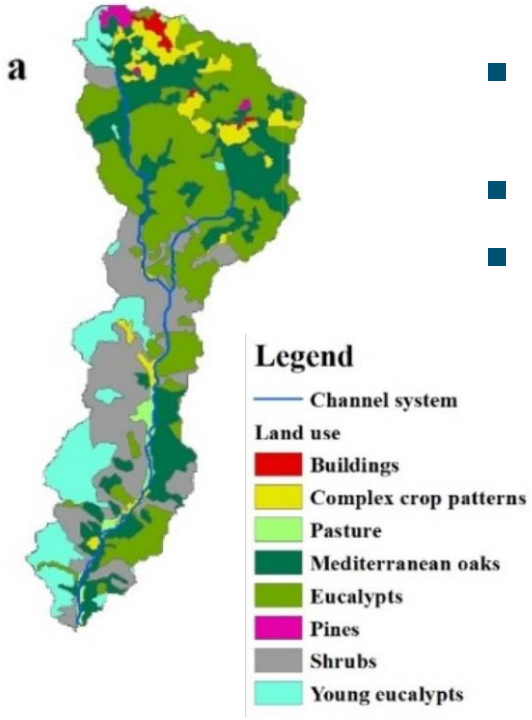
Baartman et al., 2020 Catena

OpenLISEM – process based modelling

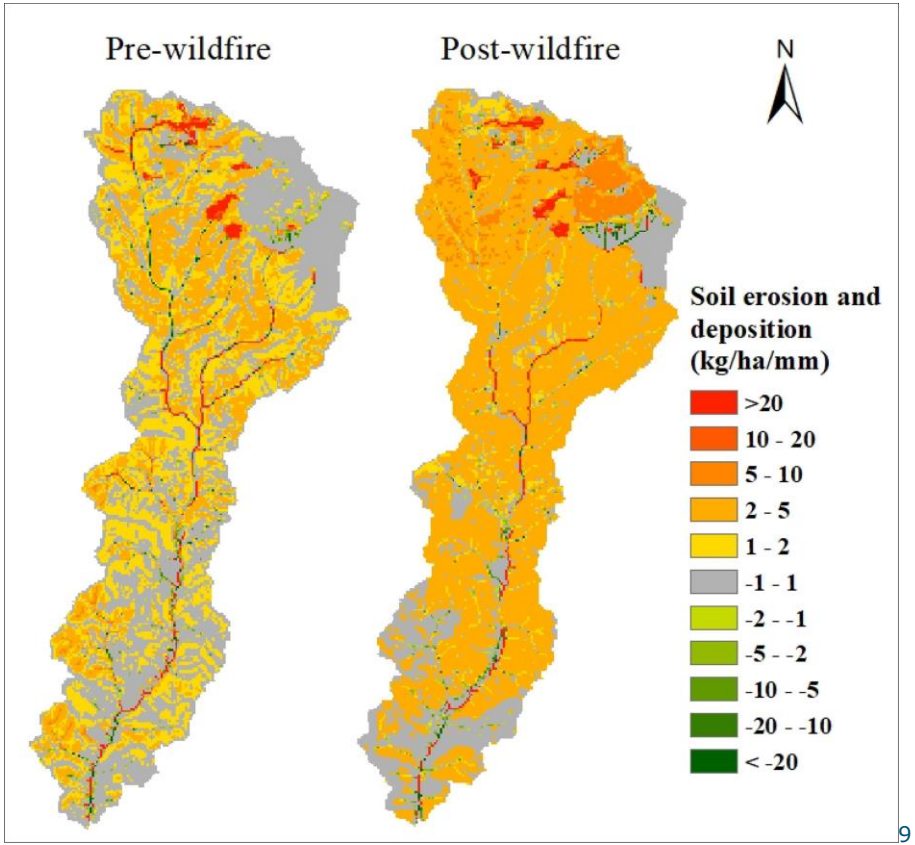
- Physically-based hydrology and soil erosion model (UTwente)
  - Event-based
  - Simulates splash & flow detachment, transport and deposition

- Test rainfall intensity & duration effects on erosion in SE Spain (Baartman et al., 2012)
- Soil & Water Conservation measures (Grum et al., 2017; MSc theses)
- Post-fire hydrology (Vieira et al., 2022) and sediment dynamics (Wu et al., 2021ab, Basso et al., 2023)

Post-wildfire modelling (OpenLISEM)



- Odeaxere catchment
- 18.5 km^2
- Wildfire: August 2003



Wu et al., 2021a

Post-wildfire modelling (OpenLISEM)

Testing the impacts of wildfire on hydrological and sediment response using the OpenLISEM model. Part 2: Analyzing the effects of storm return period and extreme events

Jinfeng Wu [a,b,d,*], Jantiene E.M. Baartman [b], João Pedro Nunes [b,c]

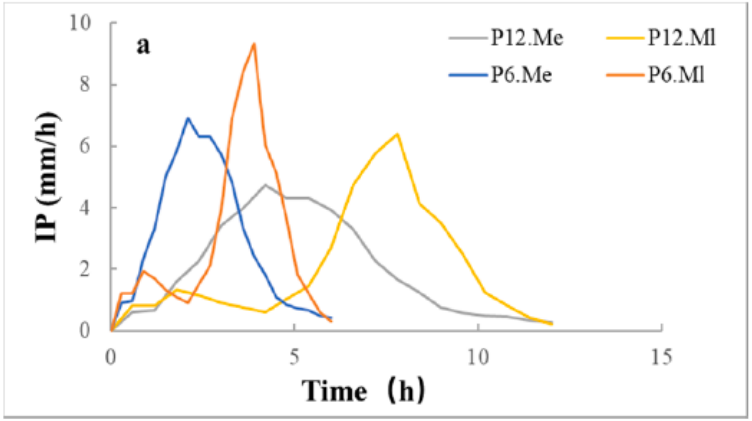


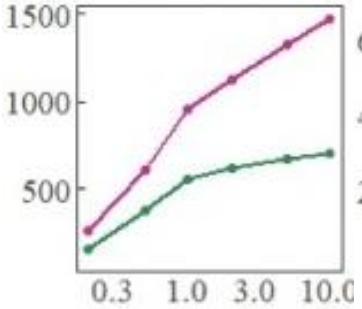
Table 2
Rainfall intensity and total rainfall as input for the OpenLISEM model for different return periods.

R (yrs)	I (mm/h) 6 h	12 h	PP (mm) 6 h	12 h
0.2	3.01	2.06	18.09	24.77
0.5	6.33	4.33	37.97	51.99
1	8.83	6.05	53.01	72.59
2	11.34	7.77	68.05	93.19
5	14.66	10.03	87.93	120.41
10	17.16	11.75	102.97	141.01

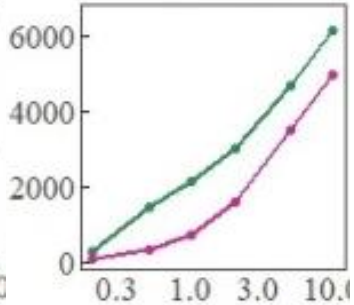
Wu et al., 2021b

Post-wildfire modelling (OpenLISEM)

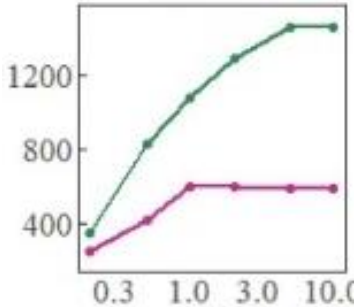
Splash detachment (ton)

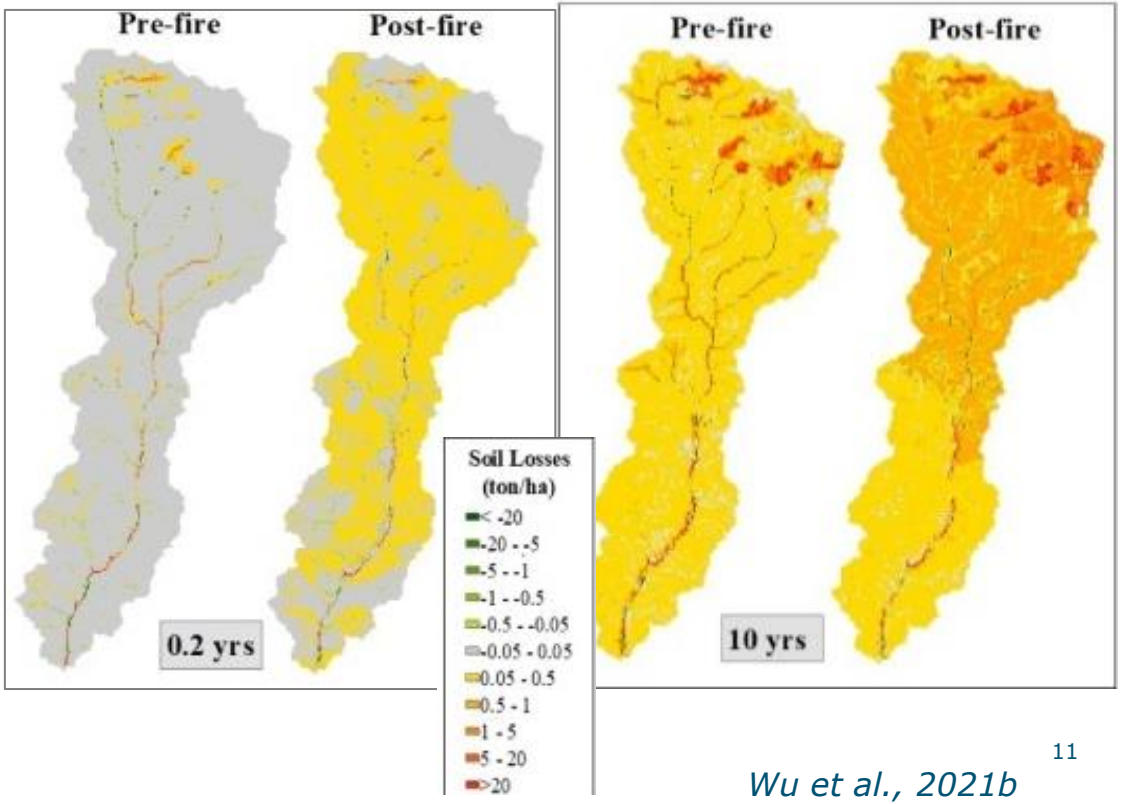


Flow detachment (ton)



Deposition(ton)

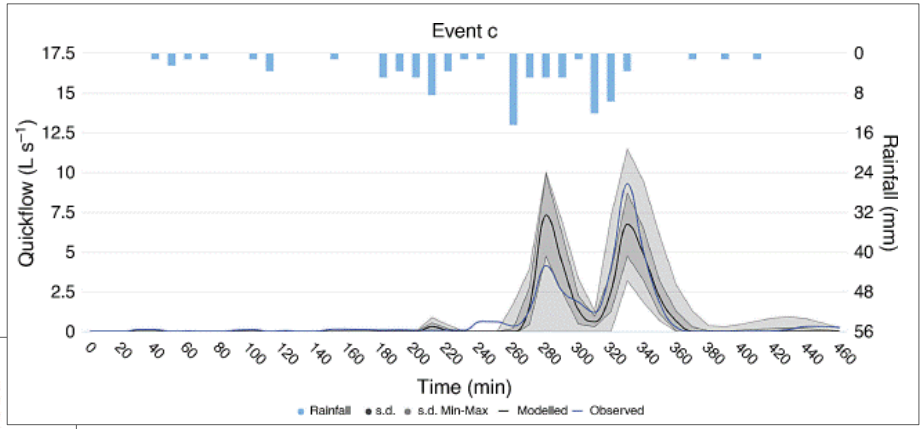


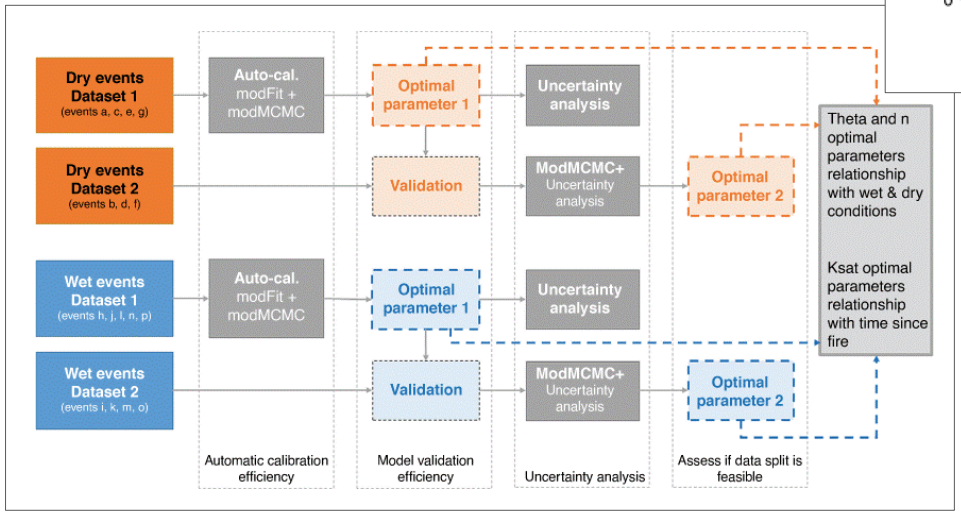


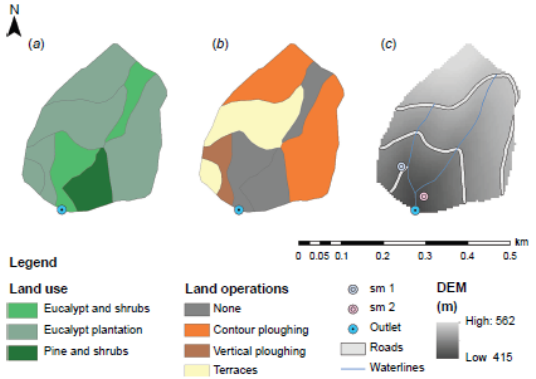
Wu et al., 2021b

Post-wildfire modelling (OpenLISEM)

- Colmeal catchment (10 ha)
- Wildfire: 27 August 2008

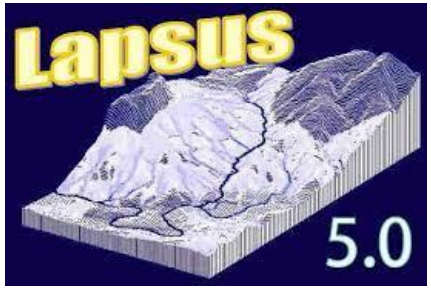






Vieira et al., 2022

LAPSUS – landscape evolution modelling



- LAPSUS – Landscape Process Modelling at Multi-dimensions and Scales (Schoorl et al., 2000, 2002)
    - Long-term sediment redistribution
- Applied to explore sediment redistribution due to multiple wildfires

RESEARCH ARTICLE

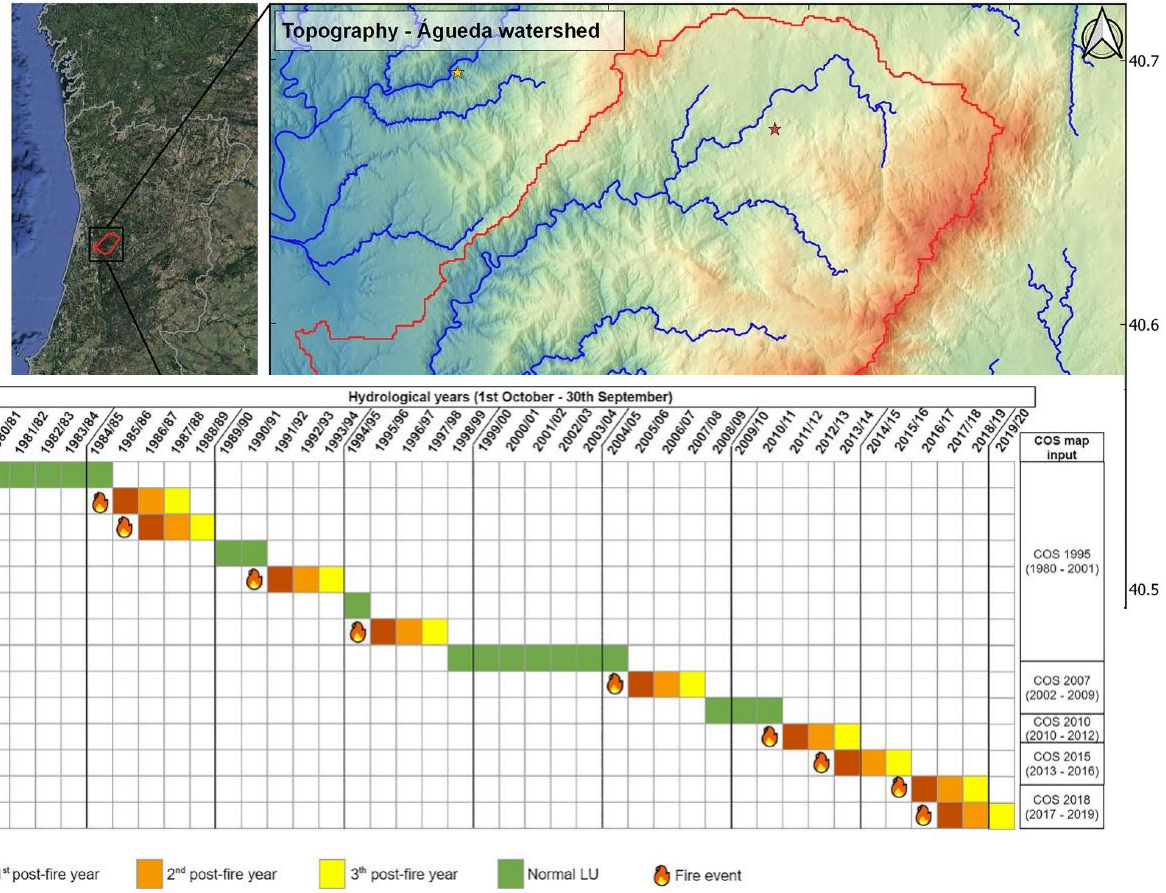
ESPL WILEY

How do large wildfires impact sediment redistribution over multiple decades?

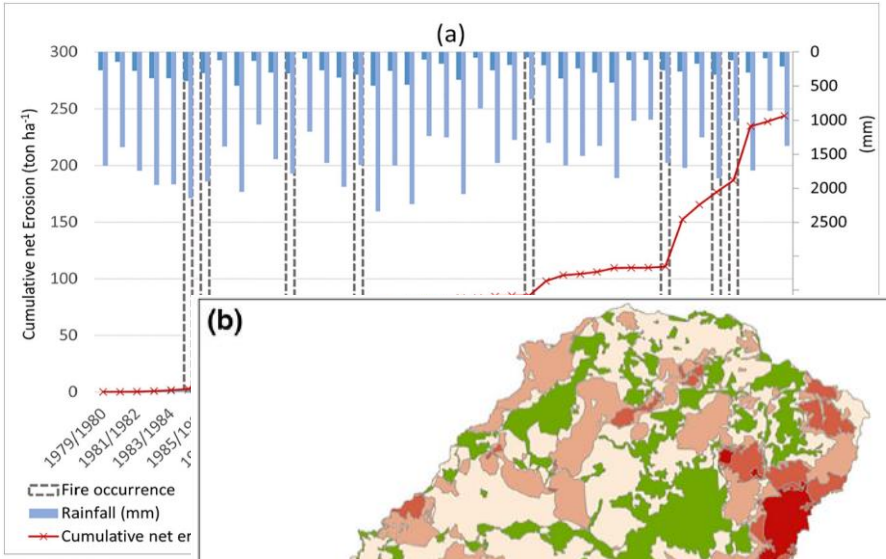
Dante Follmi[1] | Jantiene Baartman[1] | Akli Benali[2] | Joao Pedro Nunes[1,3]

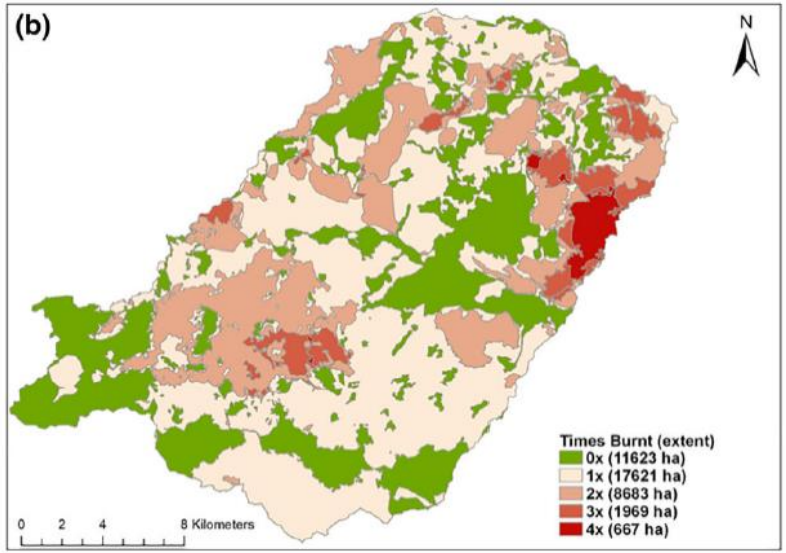
LAPSUS – multiple wildfires

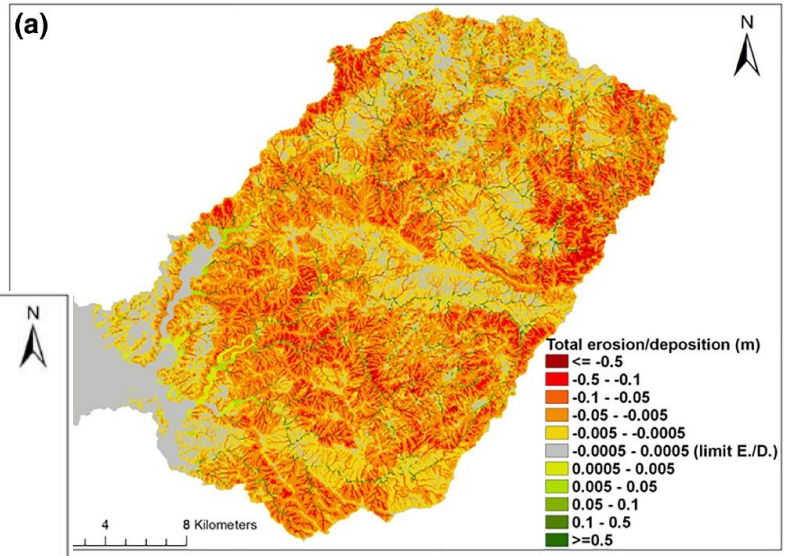
- Águeda catchment (404 km^2)
- 1000 – 2500 mm/y rainfall
- Wildfires: 1985, 1986, 1991, 1995, 2005, 2013, 2016, 2017
- 41 year simulation



LAPSUS – multiple wildfires





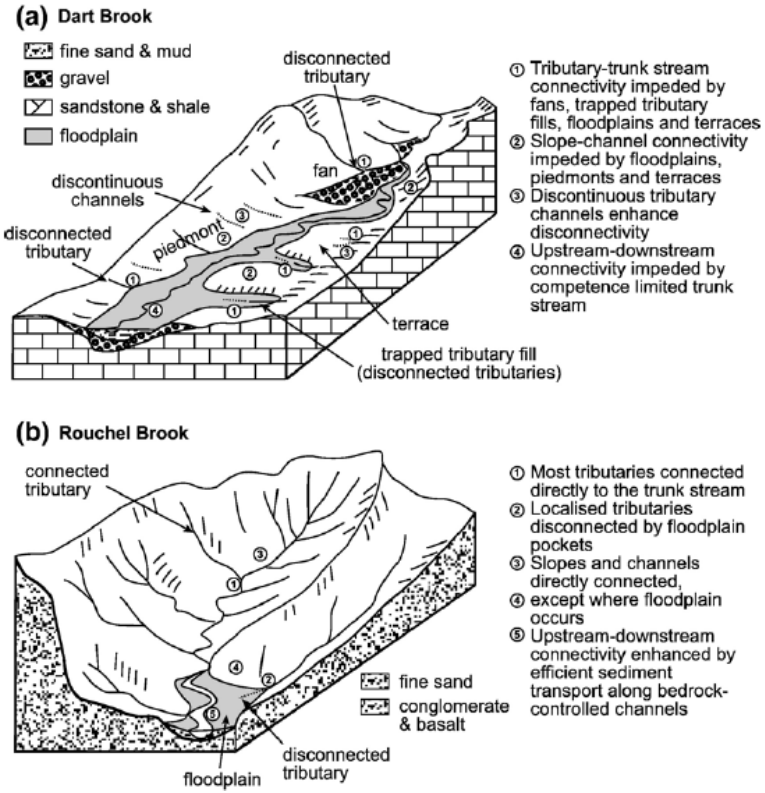


- 5.95 t/ha/y burnt vs. 0.58 t/ha/y unburnt
- Difficult to calibrate the model

Follmi et al., 2022

Sediment connectivity indices

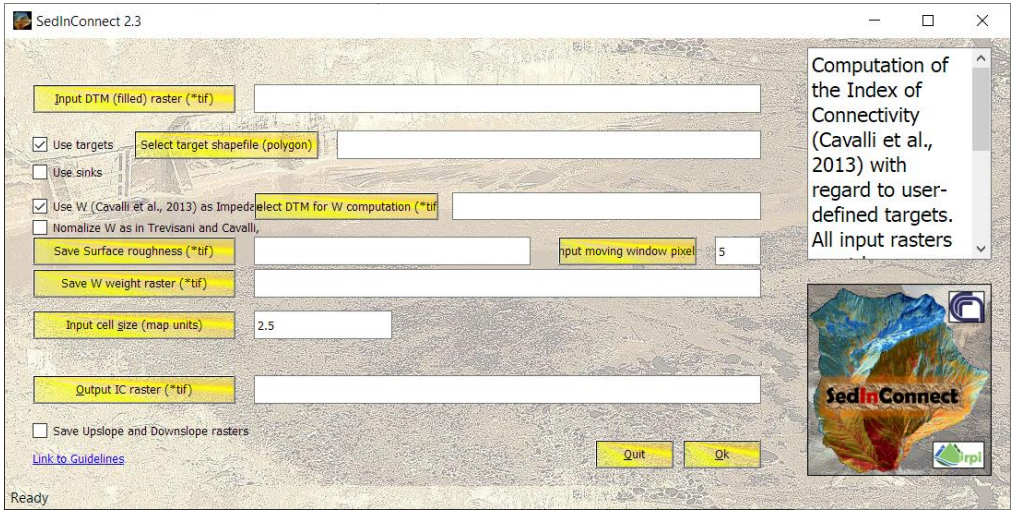
- Connectivity (e.g. Bracken and Croke, 2007):
  i. Landscape connectivity = physical coupling of landforms
  ii. Hydrological connectivity = passage of water through the catchment
  iii. Sedimentological connectivity = transfer of sediment through a basin

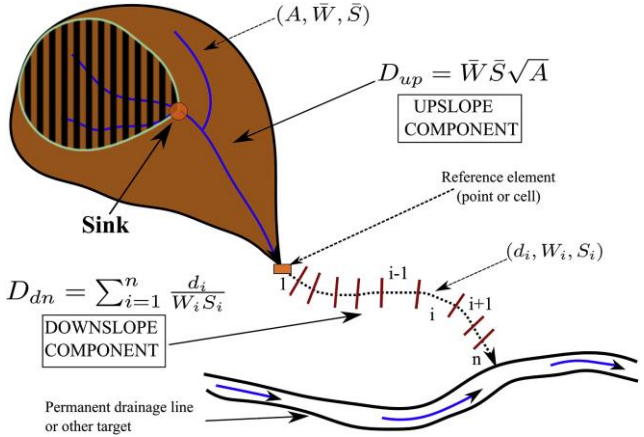


Fryirs et al., 2007

Sediment connectivity indices

- Index of Connectivity (IC)
  - Structural connectivity (terrain)
  - SedInConnect tool (Crema & Cavalli, 2018)



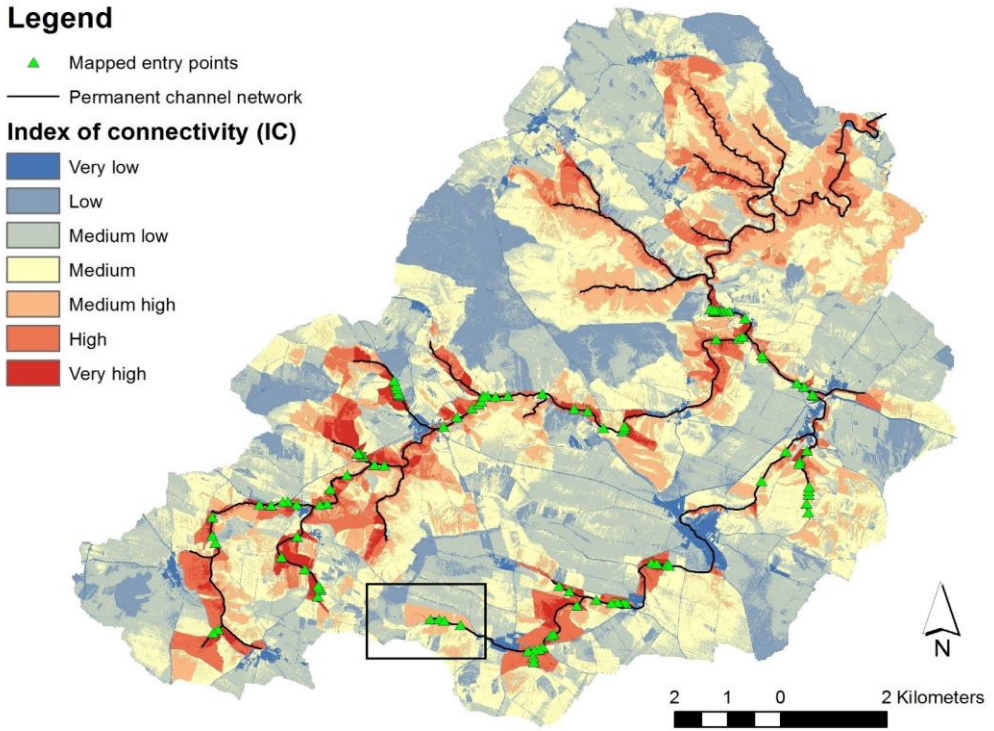


Borselli et al., 2008; Crema & Cavalli, 2018

Sediment connectivity indices

- Index of Connectivity (IC)
  - Structural connectivity (terrain)

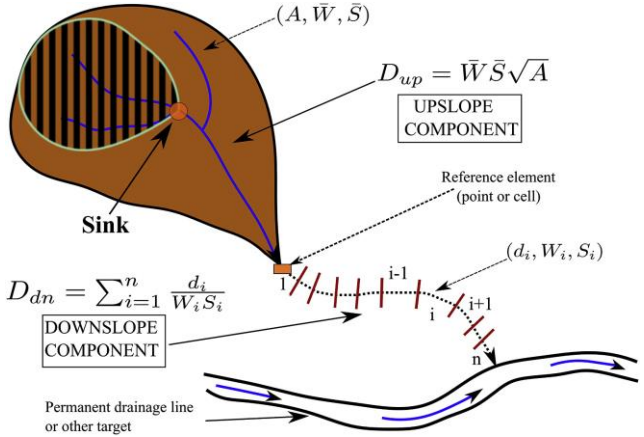
IC Class	Entry Points (%)
Very low	0
Low	1
Medium low	3
Medium	4
Medium high	7
High	21
Very high	64



Poeppl et al., 2019

Sediment connectivity indices

- Index of Connectivity (IC)
  - Structural connectivity (terrain)
- Aggregated IC (AIC) (Lopez-Vicente & Ben-Salem, 2019)
  - Functional connectivity
  - Rainfall & Soil physical properties
- Applied AIC to Wei River Basin (Loess Plateau, China)



Borselli et al., 2008; Crema & Cavalli, 2018

Intra-annual sediment dynamic assessment in the Wei River Basin, China, using the AIC functional-structural connectivity index

Zhenni Wu [a,*], Jantiene E.M. Baartman [a], João Pedro Nunes [a,b], Manuel López-Vicente [c]

Sediment connectivity in Wei River Basin (AIC)

- Largest tributary of Yellow River (135,000 km^2)

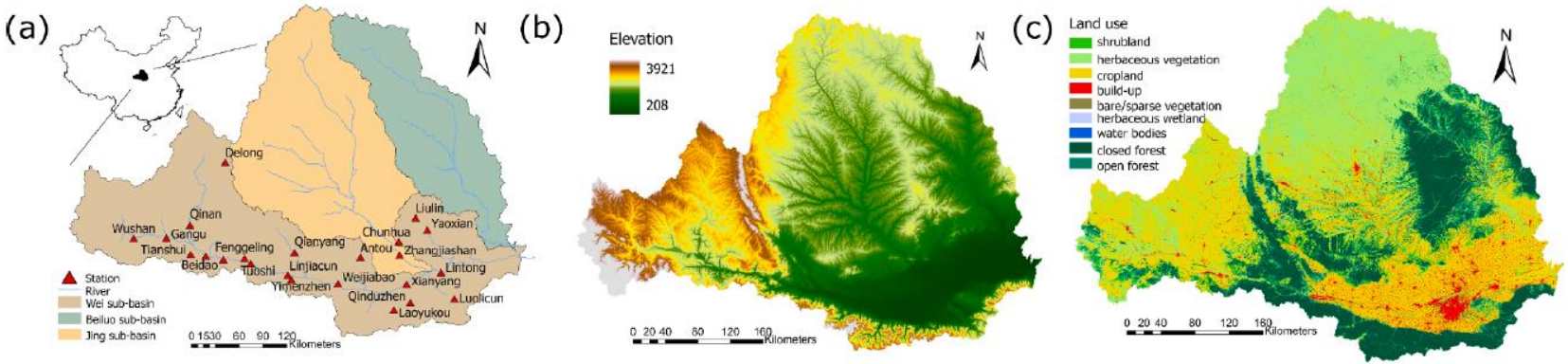


Fig. 1. Wei River Basin study area with (a) location of the sub-catchments, (b) elevation and (c) land use.

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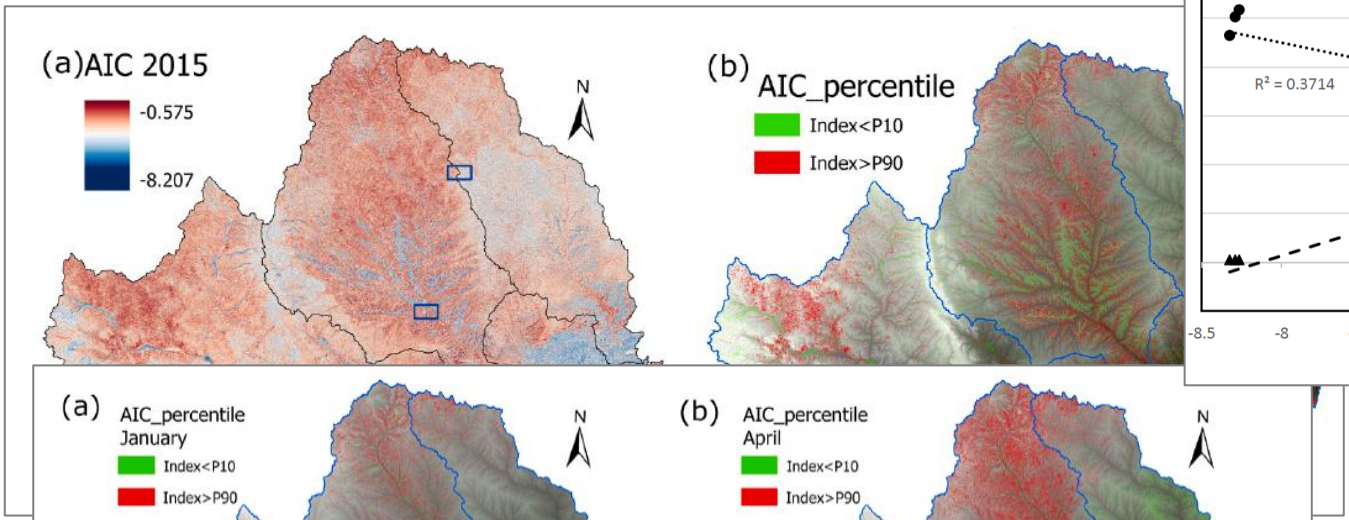
Wu et al., 2023

Sediment connectivity in Wei River Basin (AIC)



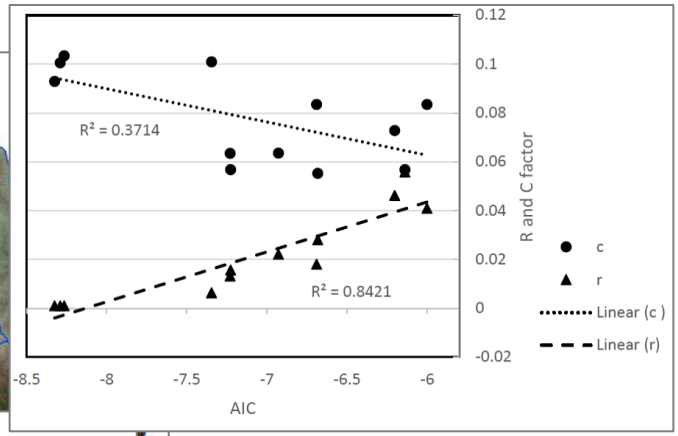


Fig. 6. AIC maps with highest (P90) and lowest (P10) 10% percentiles of AIC values for (a) January 2015 and (b) April 2015.

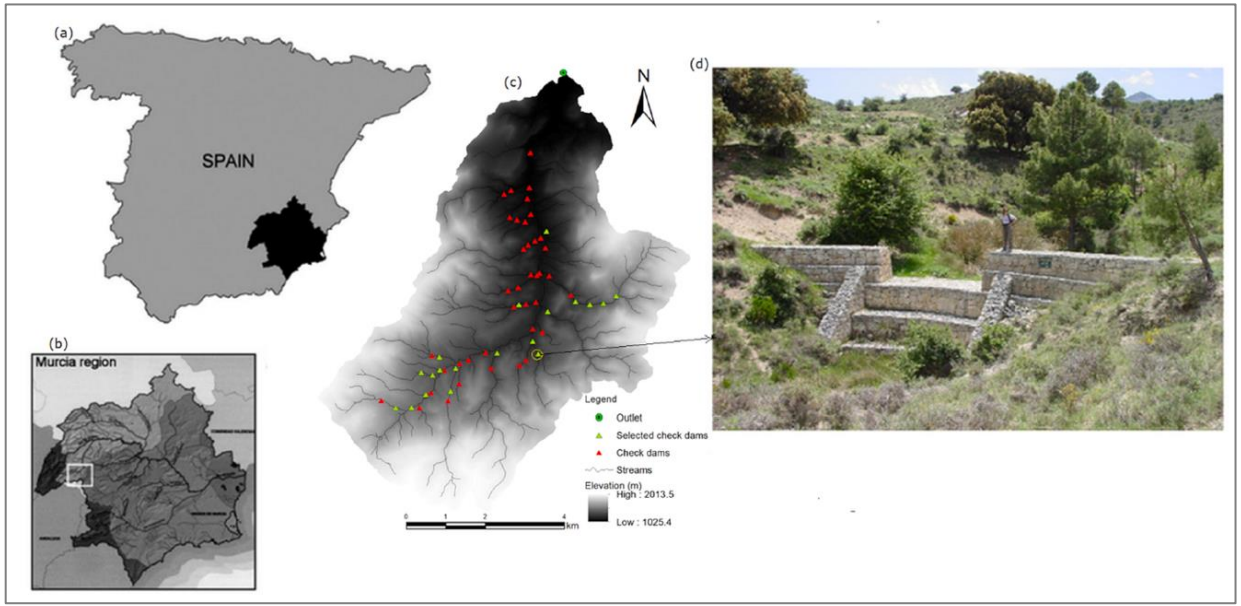
Wu et al., 2023

Combining IC & erosion modelling

- RUSLE - IC – SDR approach
  - Derive SDR based on IC map (Vigiak et al., 2012)
  - Combine with RUSLE as proxy for transport and deposition

The potential and challenges of the 'RUSLE-IC-SDR' approach to identify sediment dynamics in a Mediterranean catchment

Niguse Abebe [a,c,d,*], Joris Eekhout [b], Bart Vermeulen [a], Carolina Boix-Fayos [b], Joris de Vente [b], Berhane Grum [c], Ton Hoitink [b], Jantiene Baartman [d]



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Combining IC & erosion modelling

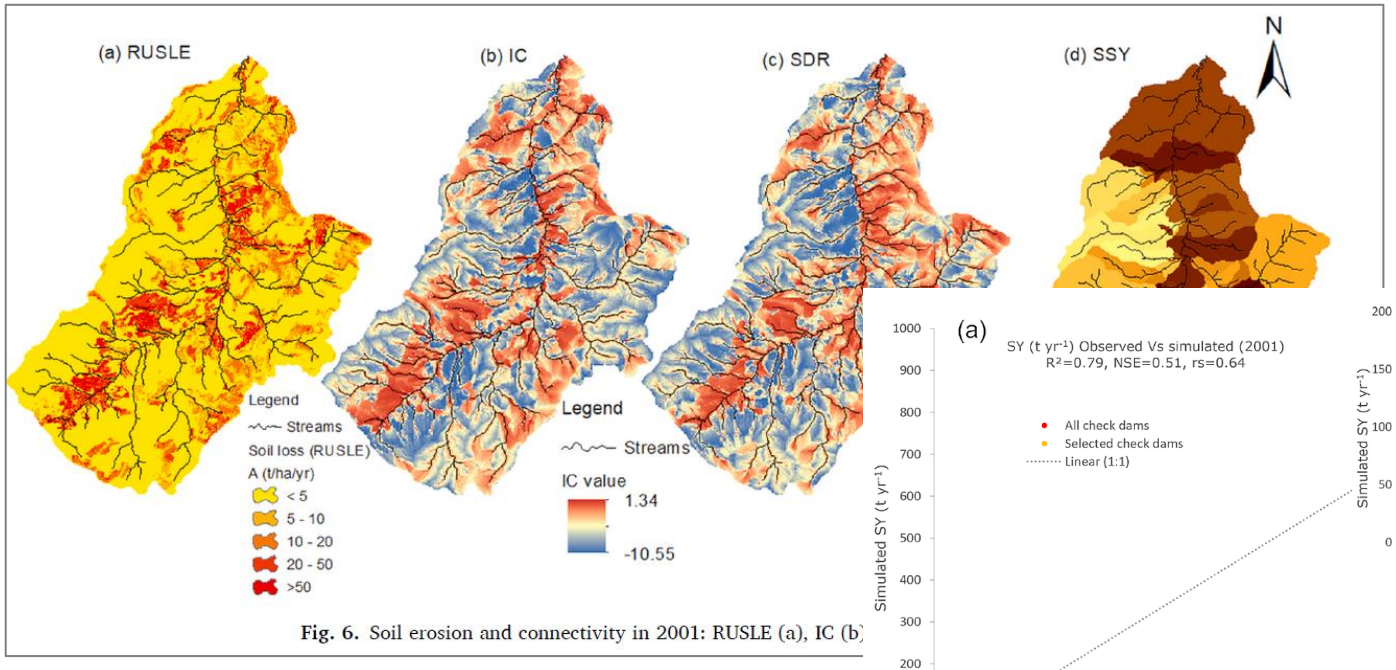
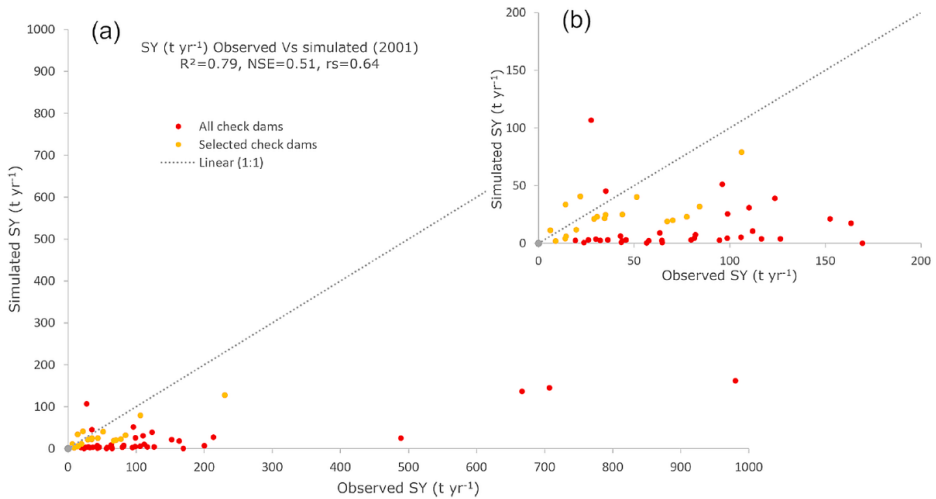


Fig. 6. Soil erosion and connectivity in 2001: RUSLE (a), IC (b)



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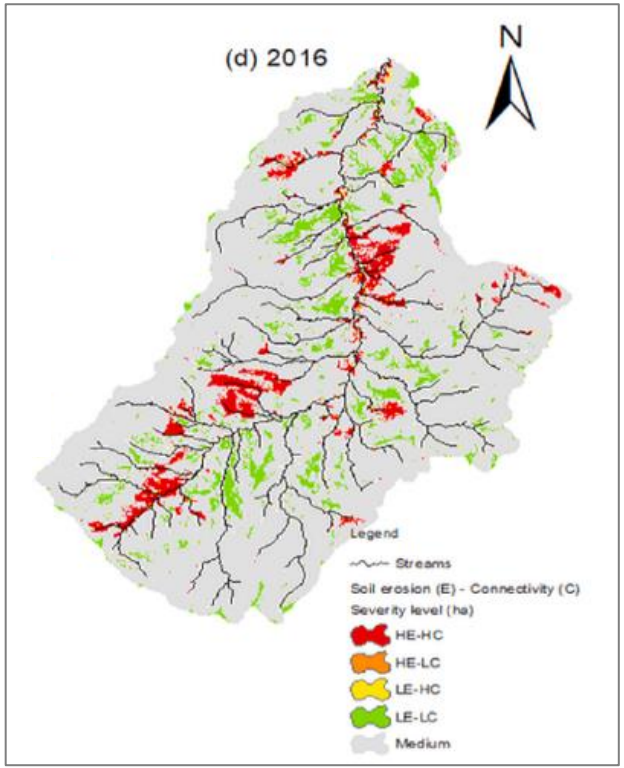
Abebe et al., 2023

Combining IC & erosion modelling



- RUSLE - IC – SDR approach
  - Low data-demanding
  - Identify source areas for soil erosion and sediment flux
  - RUSLE: no gully and channel erosion
  - Incorporate functional connectivity

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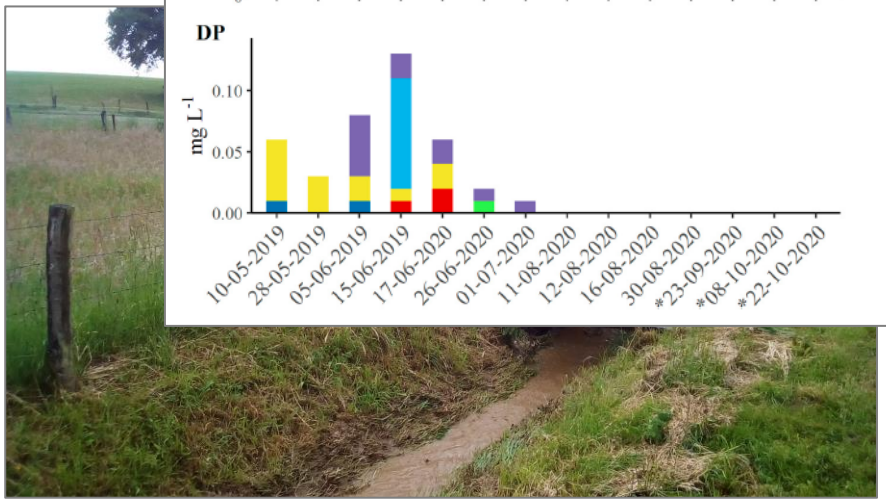
Abebe et al., 2023

Outlook – future work

- Mov



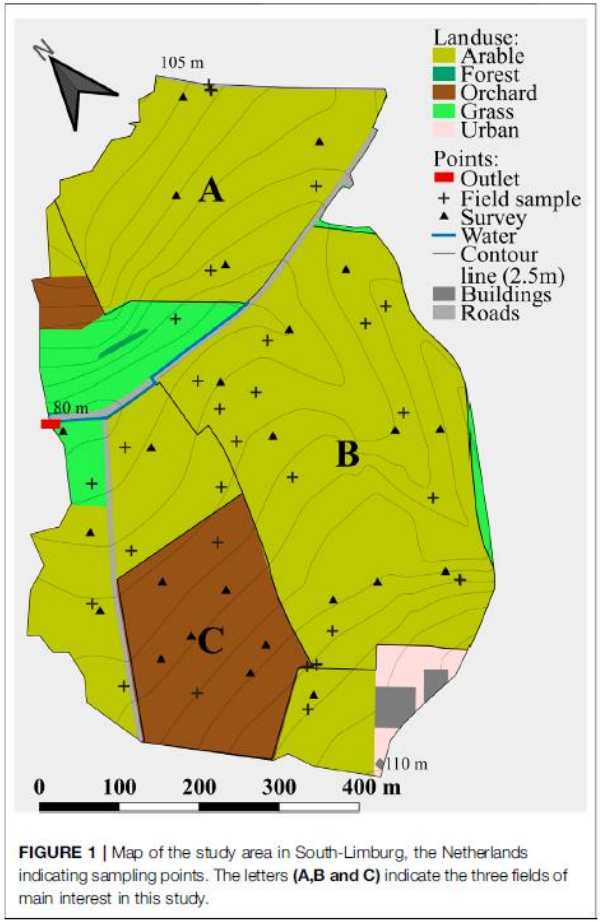
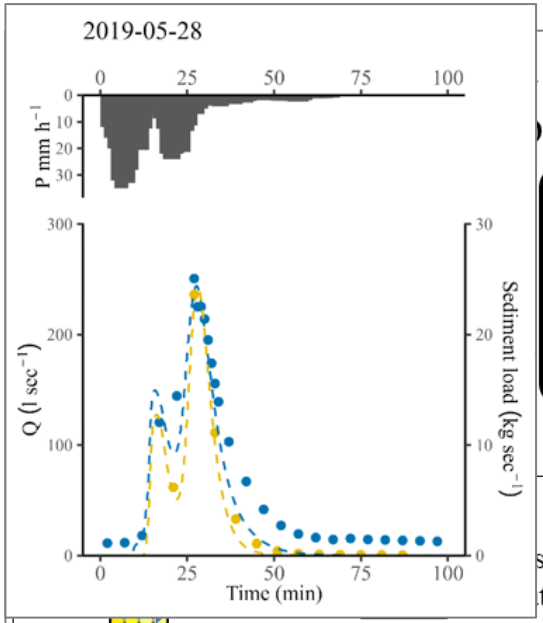


FIGURE 1 | Map of the study area in South-Limburg, the Netherlands indicating sampling points. The letters **(A,B and C)** indicate the three fields of main interest in this study.

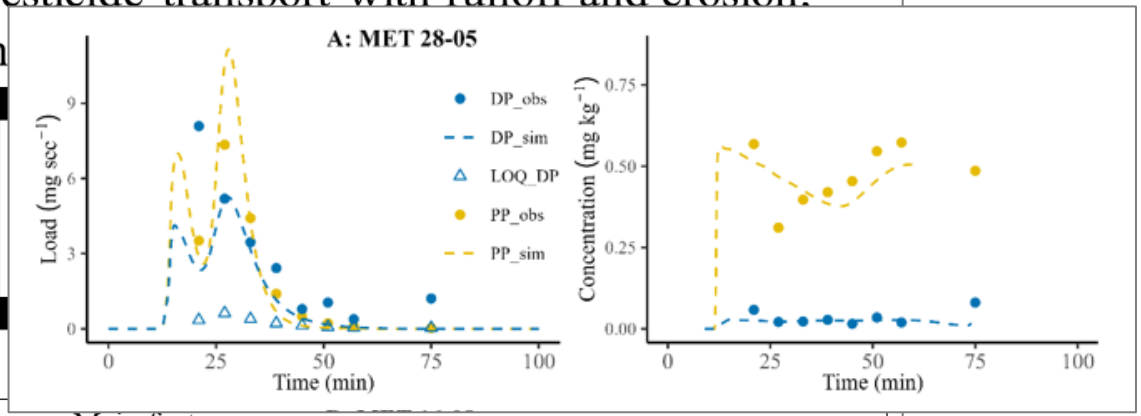
Commelin et al., 2023

Outlook – future work

- Movement of pollutants with sediments – into OpenLISEM



pesticide transport with runoff and erosion:



Main features

High temporal resolution

Erosion related transport

Commelin et al., in prep.

Outlook – future work

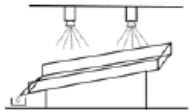
- Movement of pollutants with sediments
  - Microplastics
  - How many? Which types, sizes, etc?
  - Move with runoff, erosion
  - …eventually: model this.


Landfill Rwanda (photo: JB)

- MASTER project: How Microplastics Affect Soil structure and their TRansport with runoff and ERosion

Numerical simulation

Field experiment


Rainfall simulation experiment

Outlook – future work

- LandEX: Impro
  adapt and miti
  - Improve
    (floods a
    adaptati
  - Connect
  - Close co

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Thank you!

TERENO-OZCAR Conference
27 Sept 2023
Jantiene Baartman
Jantiene.baartman@wur.nl

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