Insights into the suspended sediment transport in the Rur River

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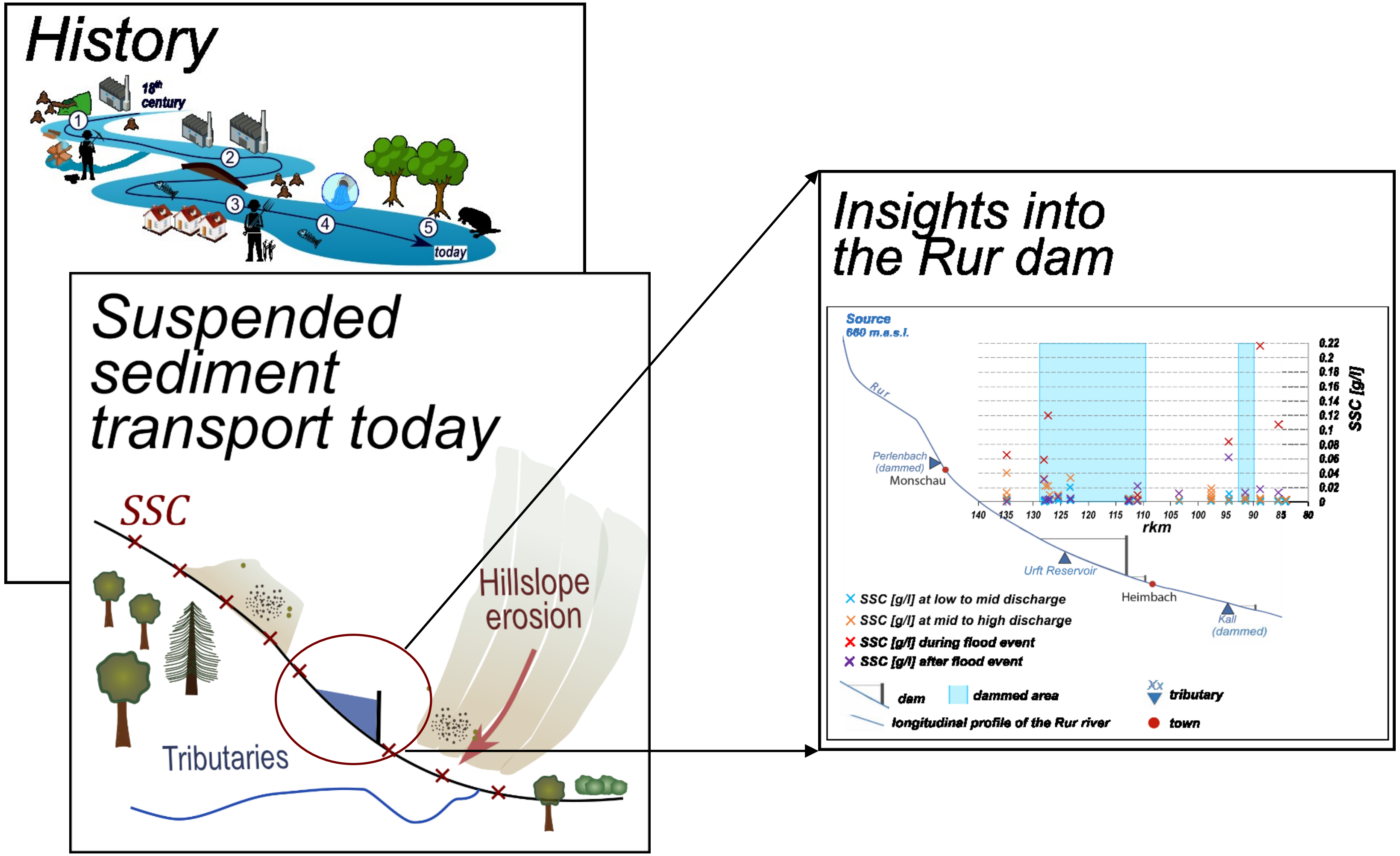
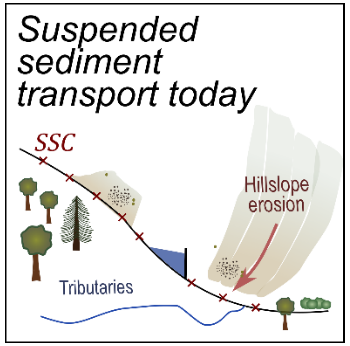
Content


History
18th century
today
Suspended sediment transport today
SSC
Hillslope erosion
Tributaries
Insights into the Rur dam
Source
660 m.a.s.l.
Rur
Perlenbach (dammed)
Monschau
Urft Reservoir
Heimbach
Kall (dammed)
rkm
SSC [g/l]
SSC [g/l] at low to mid discharge
SSC [g/l] at mid to high discharge
SSC [g/l] during flood event
SSC [g/l] after flood event
dam
dammed area
tributary
longitudinal profile of the Rur river
town

Suspended sediment transport today



$$SSC = \alpha \cdot Q^{\beta} + \epsilon_i$$

$$SSC_{i+1} = SSC_i + (\alpha \cdot Q_{i+1}^{\beta} - \alpha \cdot Q_i^{\beta}) + \epsilon_i$$

With:

$SSC\ (e.g.\ \left[\frac{mg}{l}\right])$	suspended sediment concentration
Q	Discharge
α, β	parameters fitted by least squared regression
ϵ_i	normally distributed independent error

Source: Campbell and Bauder 1940, Ferguson 1986

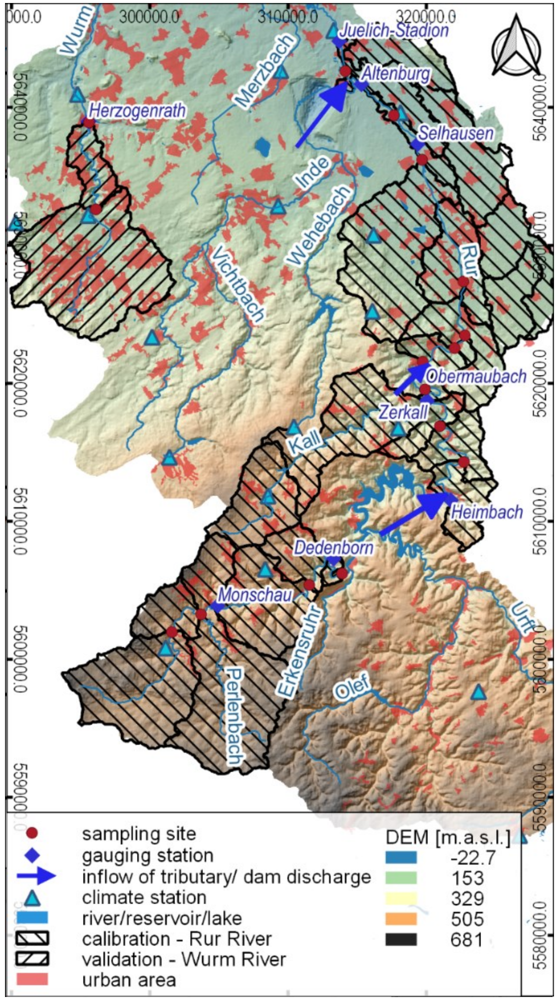
Suspended sediment transport today

Aim:

- Extend the sediment rating curve with existing knowledge
- Discuss the influence of different parameters on the sediment concentration within a river section

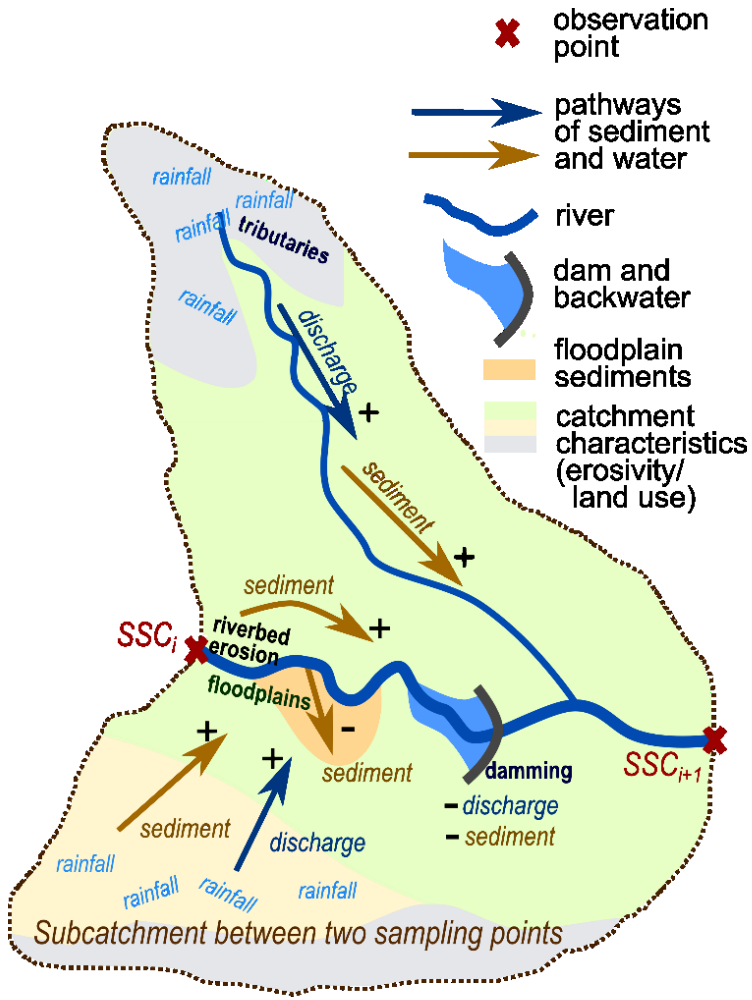
- 129 Rur Samples (calibration+testing) [13 pairs]
- 16 Wurm Samples (validation) [1 pair]

Discharge



Study area; (1) sampling sites and (2) rainfall-runoff model
Source: Wolf et al. 2023

Suspended sediment transport today



Schematic illustration of water and sediment pathways within a sub-catchment between two observation points of the suspended sediment concentration (SSC_i and SSC_{i+1}), Source: Wolf et al. 2023

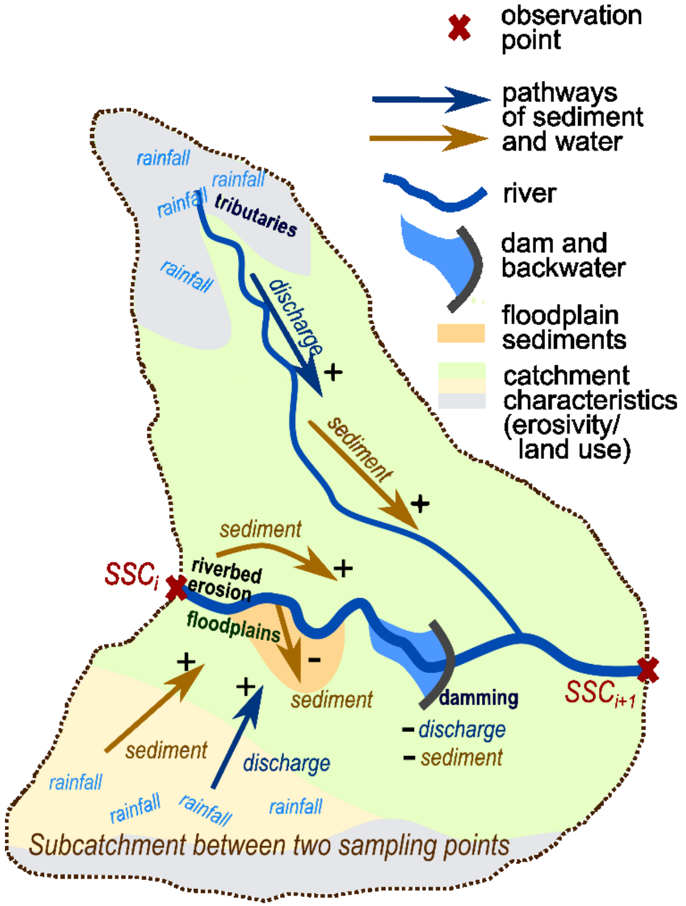
Process	(known) Influence on SSC
Rainfall on sub-catchment between two sampling sites	Increase, when erodibility of sub-catchment is high
Discharge-related processes over a river section	Increase, when riverbed erodes due to high discharges Decrease when sediments are deposited on floodplains or in other areas of reduced flow Decrease when only discharge increases but no sediment is entering
Damming	Decrease
Tributaries	Usually, increase

Suspended sediment transport today

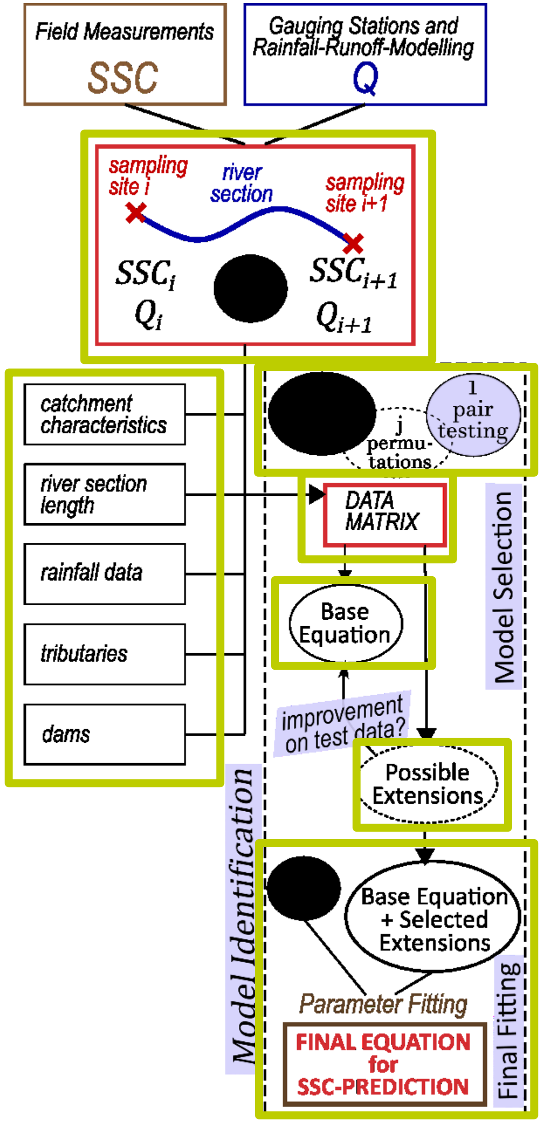
Possible extension	Parameter	Optional
Scaling discharge related transport processes over river section	Section length	
Sediment deposit due to damming	Dammed length	Discharge reduction
Sediment entry by tributaries	Tributary discharge	Rainfall Subcatchment erosivity
Sediment entry due to hillslope erosion	Subcatchment erosivity Subcatchment size Rainfall	Section length
Riverbed erosion or floodplain deposition	Section length Discharge reduction	

Terms

Data Matrix



Suspended sediment transport today



$$SSC_{i+1} = SSC_i + \left(\alpha_Q \cdot Q_2^{\beta_Q} - \alpha_Q \cdot Q_1^{\beta_Q}\right) \cdot p_{rkm}$$

$$- p_{dam} \cdot \alpha_{dam} \qquad [Damming]$$

$$- p_{rkm} \cdot \frac{Q_i}{Qi+1} \cdot a_{rkm} \qquad [Sediment\ deposition]$$

Wolf et al. 2023

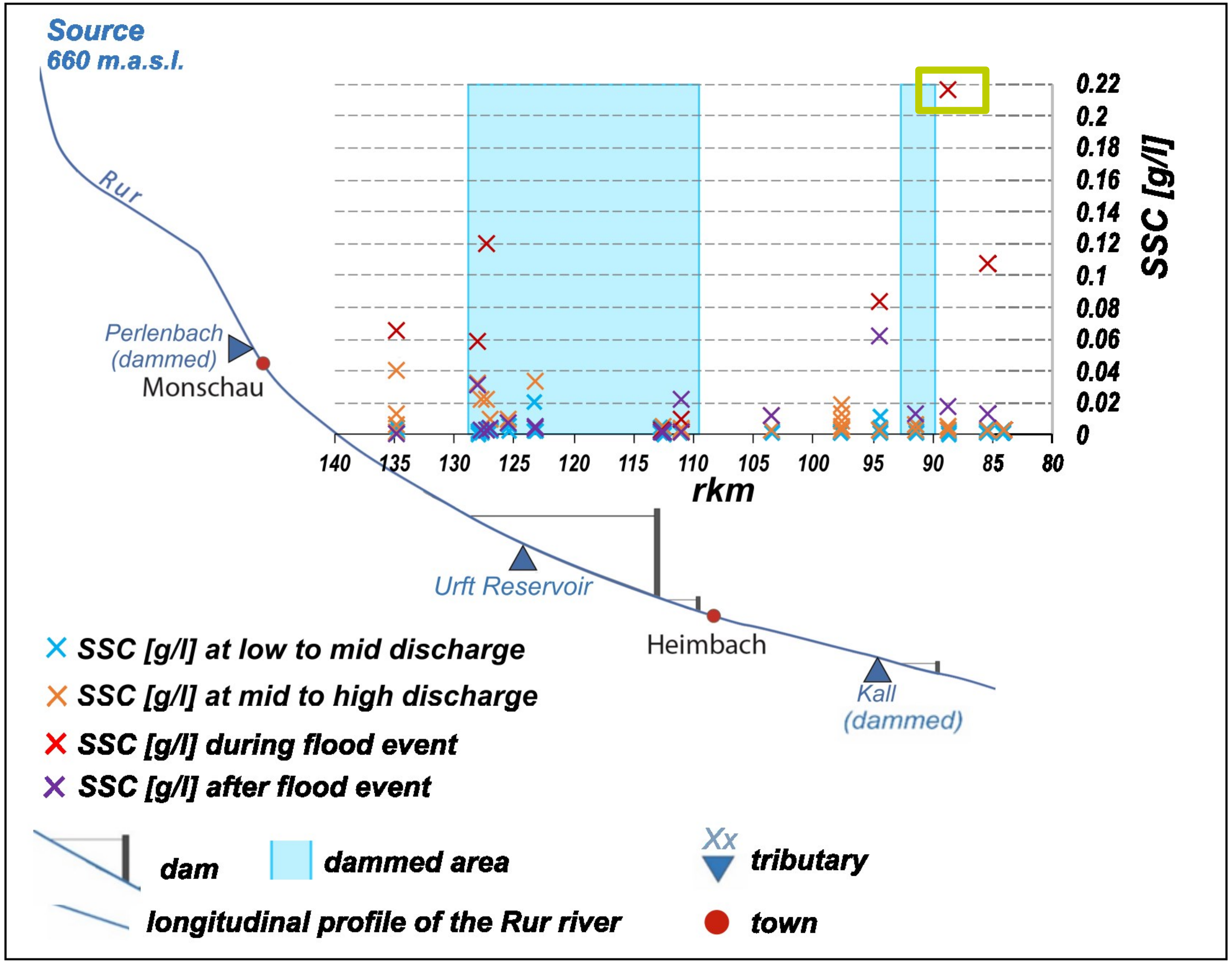
Suspended sediment transport today

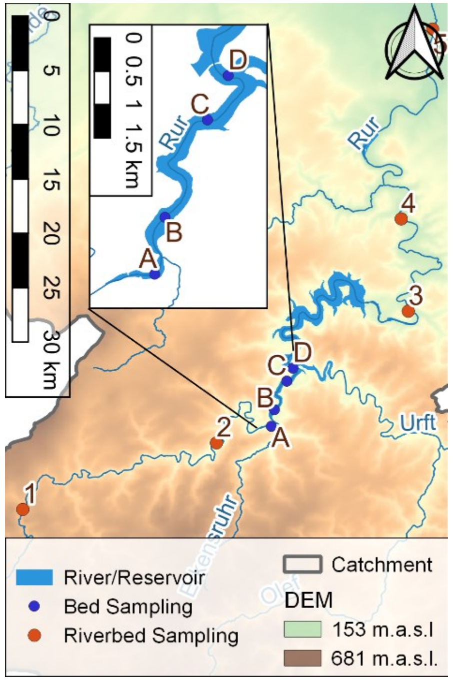
Scenario	R^2		RMSE	
	SSC_i - SSC_{i+1}	$SSC_{i+1, computed}$ - $SSC_{i+1, measured}$	SSC_i - SSC_{i+1}	$SSC_{i+1, computed}$ - $SSC_{i+1, measured}$
Rur River	0.876	0.878	152.27%	131.83%
Wurm River	0.333	0.340	54.97%	55.54%

Conclusion:

- [Accuracy within the boundaries of field work and rainfall-runoff-modelling]
- Accuracy increased by linear terms
- Added terms: damming and sediment deposition along the river section‘s length
- Limited transferability
    - Different connectivity, different functional scales

Impact of the Rur dam - SSC





Source: Wolf et al. 2022

Main impacts of a dam

1. sediment deficit (Williams und Wolman 1984; Brousse et al. 2020, Kondolf 1995)

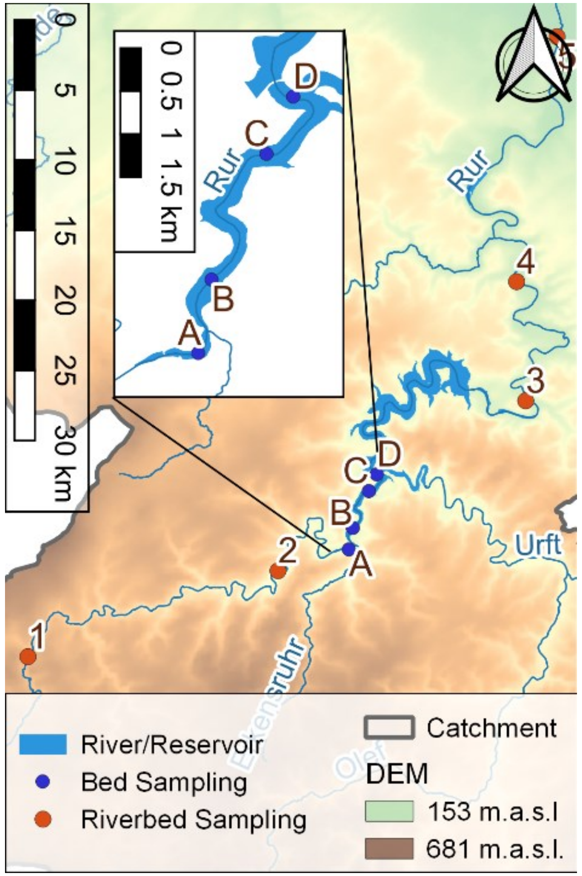
   FIELD DATA

2. increase of mean grain size diameter (Williams und Wolman 1984; Kondolf 1997, Kantoush et a. 2010)

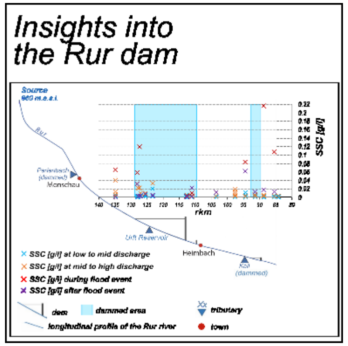
   FIELD DATA

3. Alteration of flow regime, often reducing the mean annual discharge (Adib et al. 2016, Brandt 2000, Rovira und Ibàñez 2007, Walling 2012, Brousse et al. 2020, Phillips et al. 2005)

   NUMERICAL MODELLING

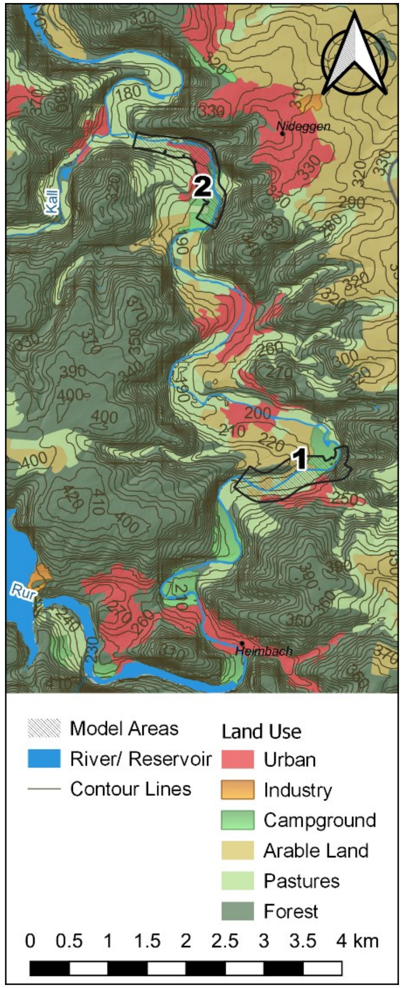


The Rur dam, source: Wolf et al. 2022

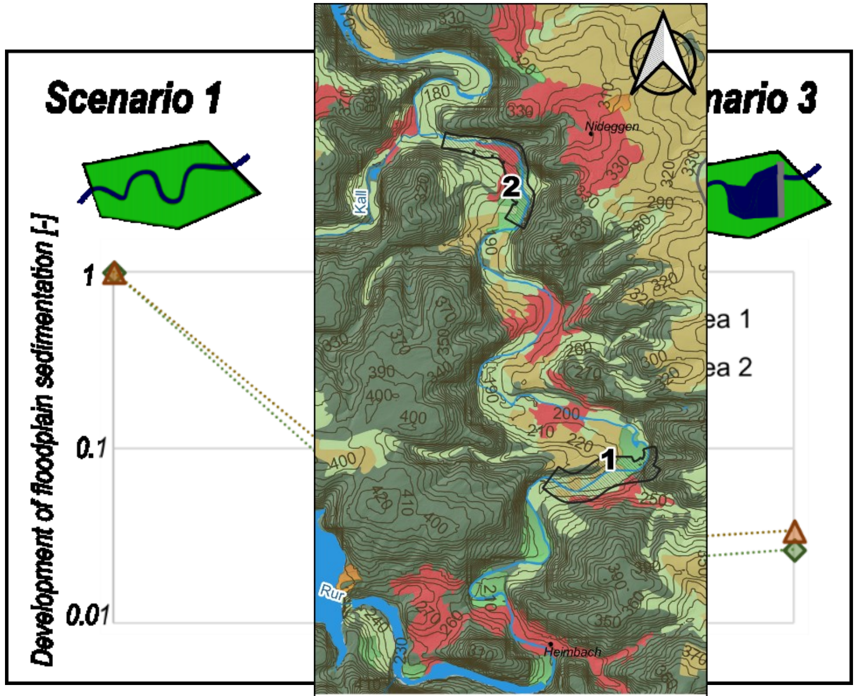


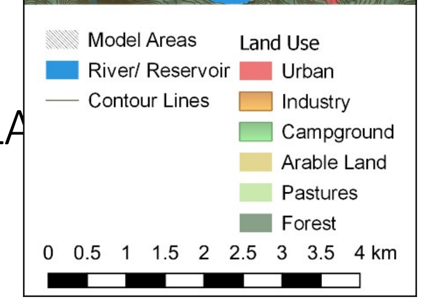
Impact of the Rur dam – Fine fraction and discharge

	Description	Inflow - Discharge	Inflow - Sediment	Sediment settling velocity
1	**Pre-dam** conditions 	Pre-dam discharge	No sediment deficit, SSC=0.00922 g/l	Small mean sediment diameter, v = 0.188 mm/s
2	Impacts **after dam**  nt	Post-dam discharge	Sediment deficit, SSC=0.0018 g/l	Small mean sediment diameter, v = 0.188 mm/s
3	**Today's situation**;  has … er … has increased	Post-dam discharge	Sediment deficit, SSC=0.0018 g/l	increased mean sediment diameter, v = 0.383 mm/s



Impact of the Rur dam

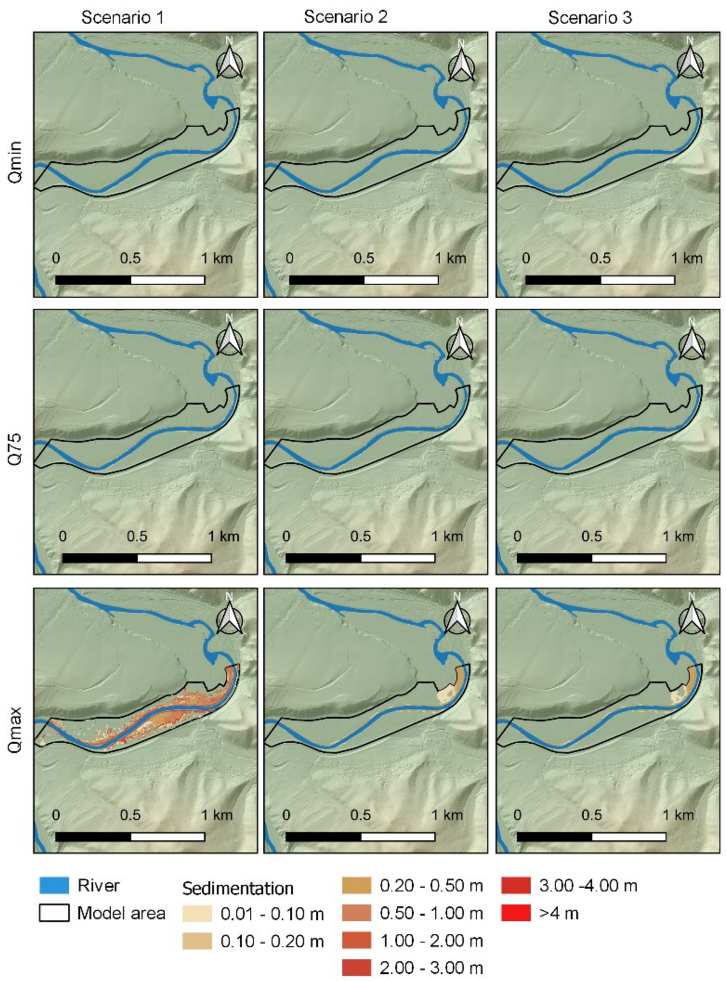


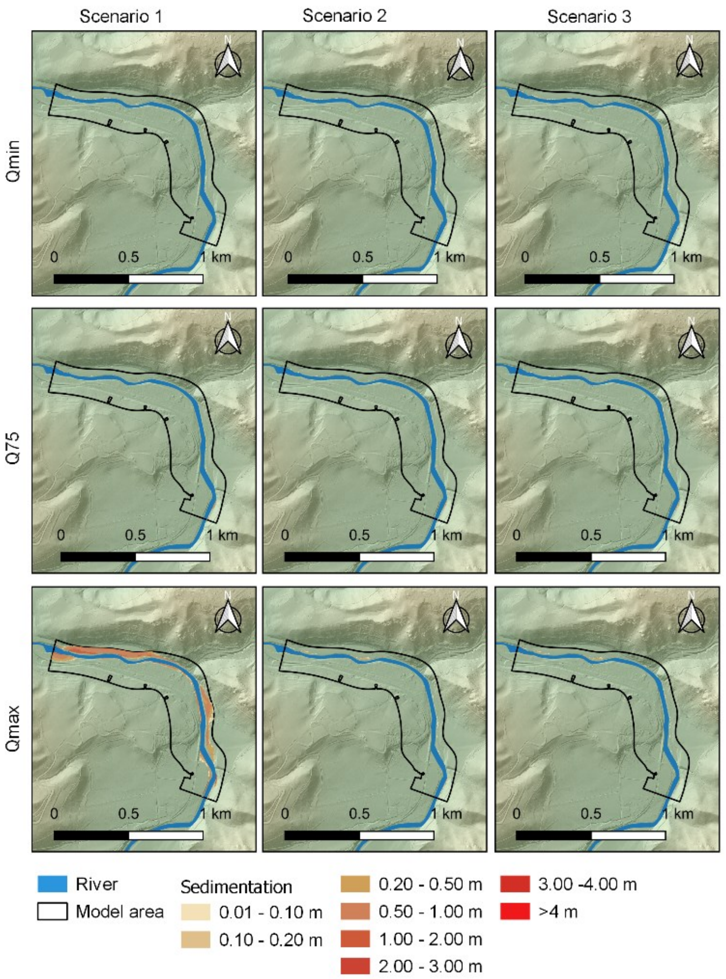


Conclusion:

- FLOODPLA

Sedimentation / Water depth





Source: Wolf et al. 2022

Thank you for your attention!

Sources

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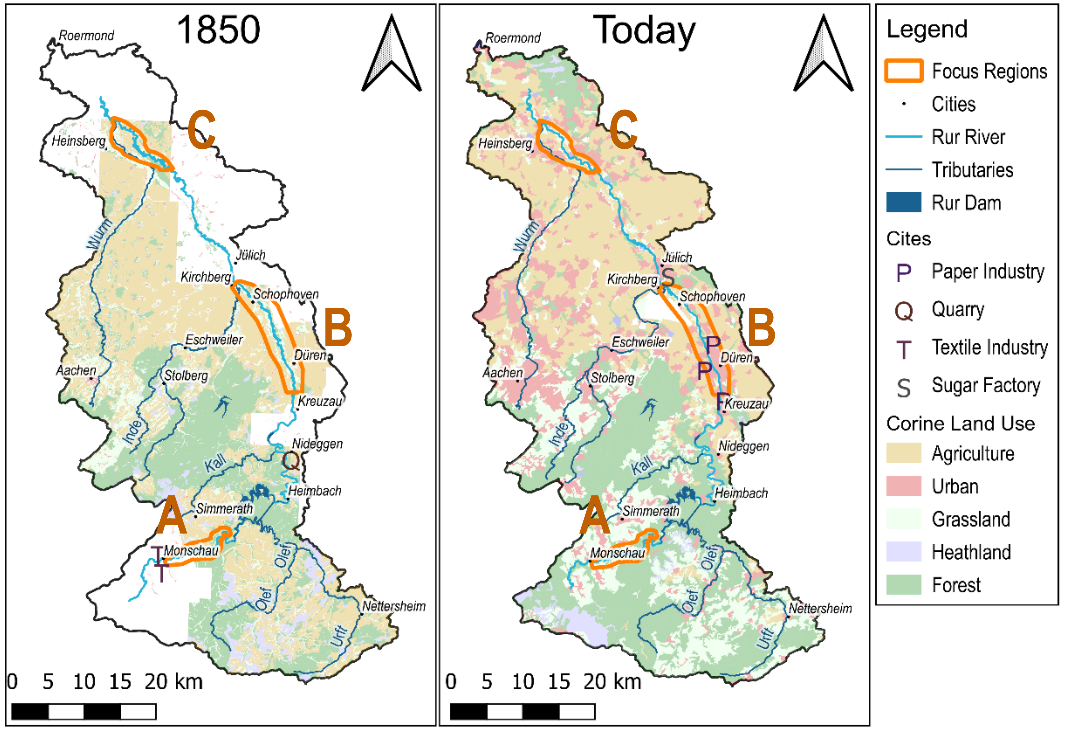
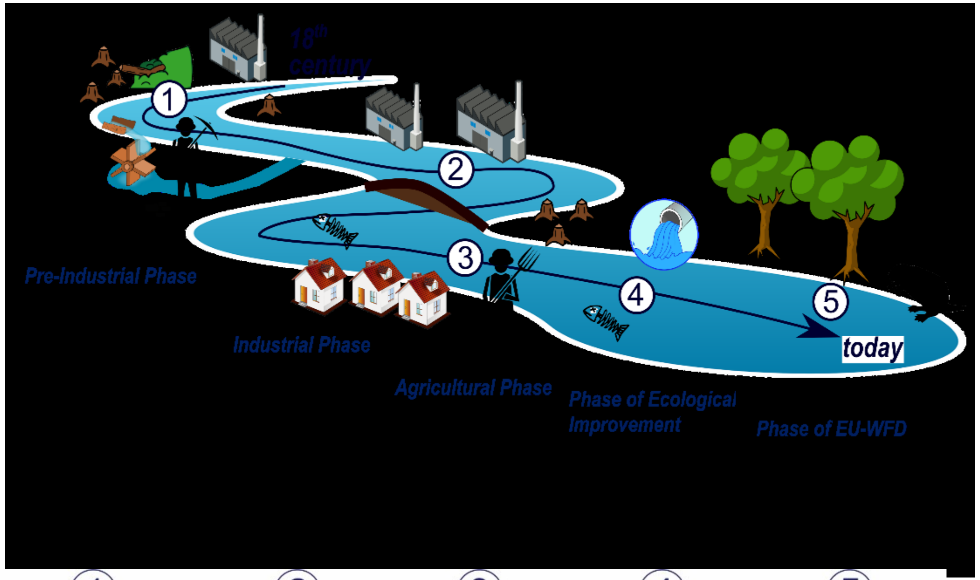
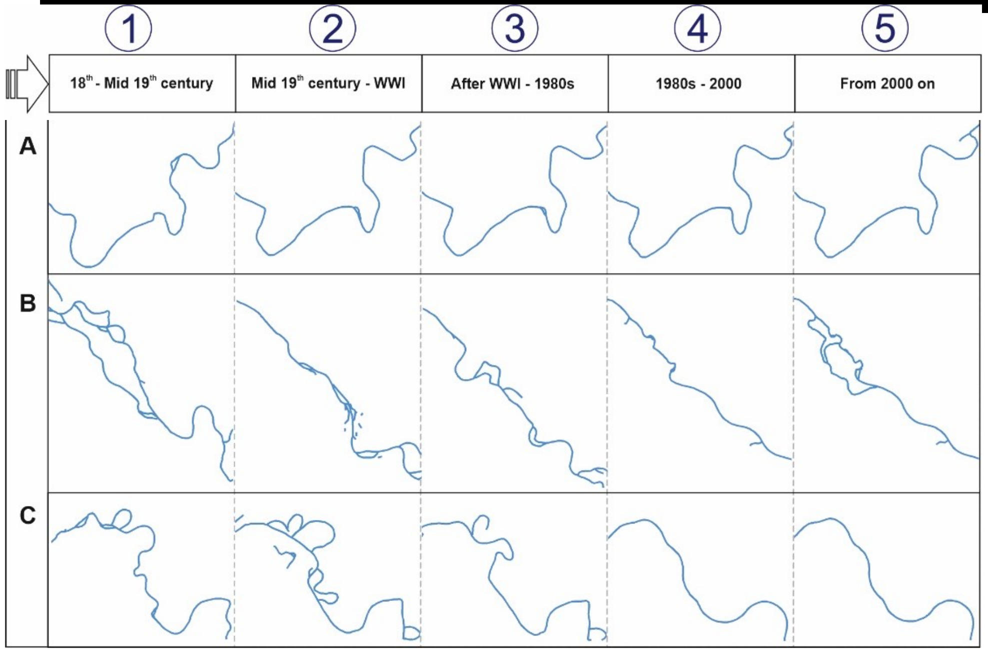
Human impact on the Rur River



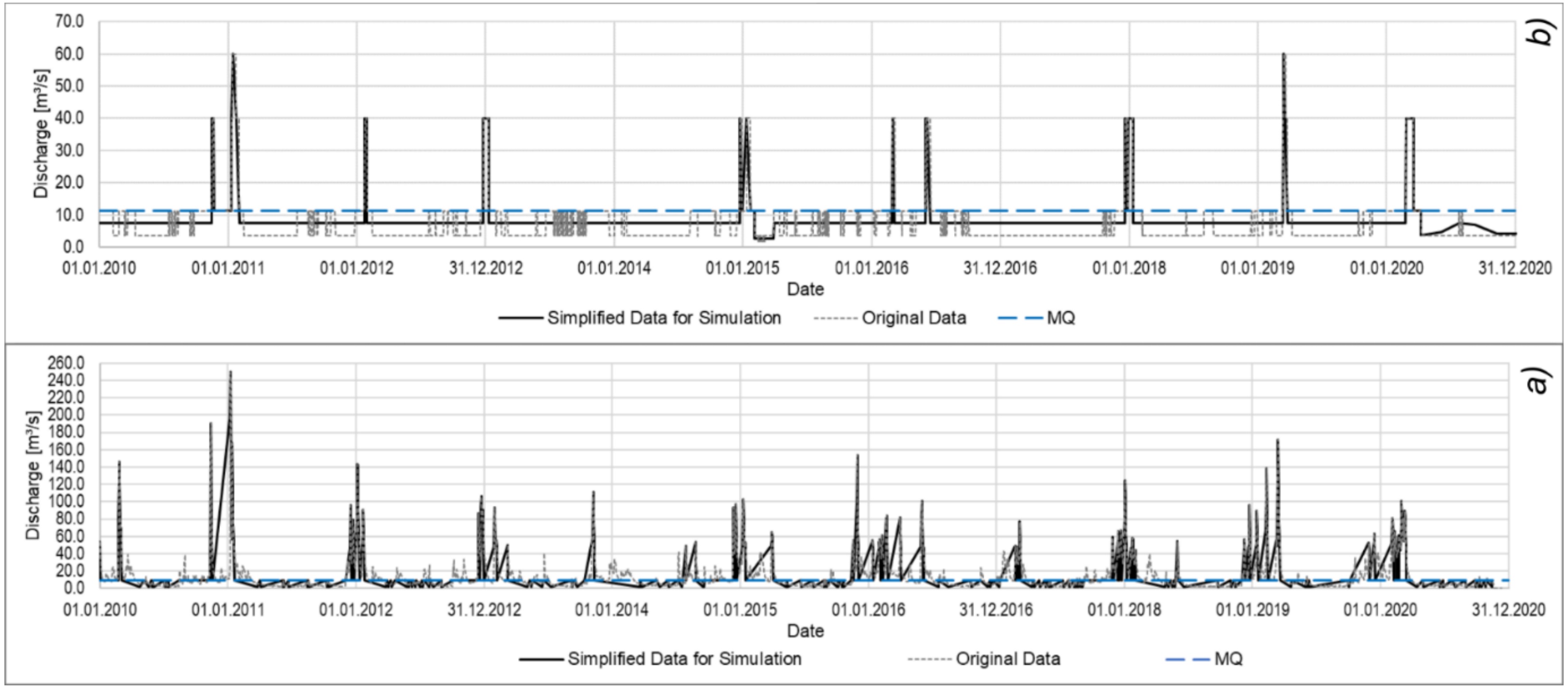




All Images from Wolf et al. 2021

Methods: Impacts of a dam

Flow alteration



Timelines of discharge for the simulation.

a) tailored timeline resembling pre-dammed conditions (grey dashed) and simplified timeline for simulation (black), MQ=9.4 m³/s.

b) b) timeline showing dam discharge (grey dashed) and simplified timeline for simulation (black), MQ=11.3 m³/s.

Suspended sediment transport today

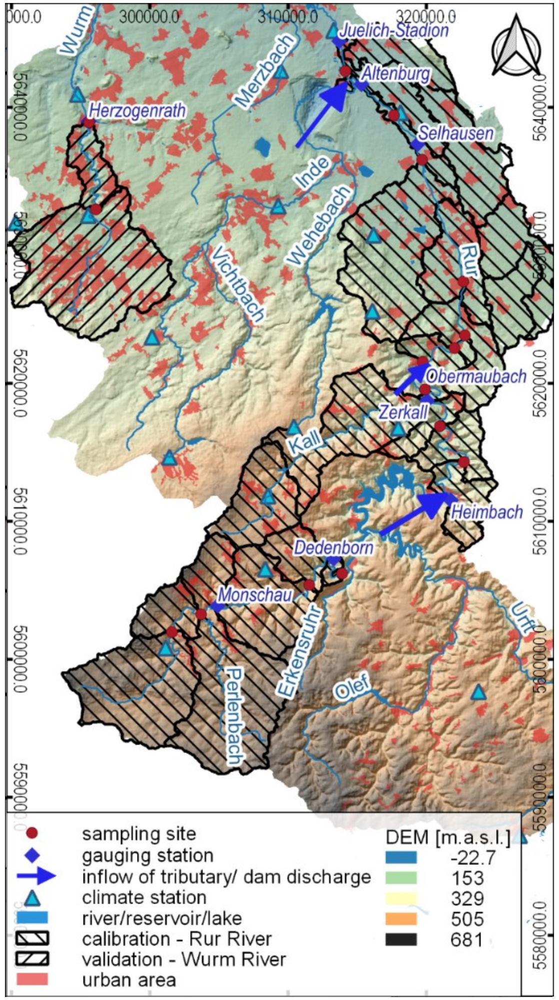
Aim:

- Extend the sediment ration curve with existing knowledge
- Discuss the influence of different parameters on the sediment concentration within a river section

- 129 Rur Samples (calibration+testing) [13 pairs]
- 16 Wurm Samples (validation) [1 pair]

	Volume Error [%]	Hydrological Deviation [-]	Nash Sutcliffe Efficiency [-]
Rur River sub-model 1	9.93	0.72	0.37
Rur River sub-model 2	1.57	0.32	0.89
Rur River sub-model 3	-0.79	0.47	0.97
Rur River sub-model 4	5.37	0.27	0.98
Rur River sub-model 5	24.41	0.56	0.85
Wurm River	7.98	0.62	0.71

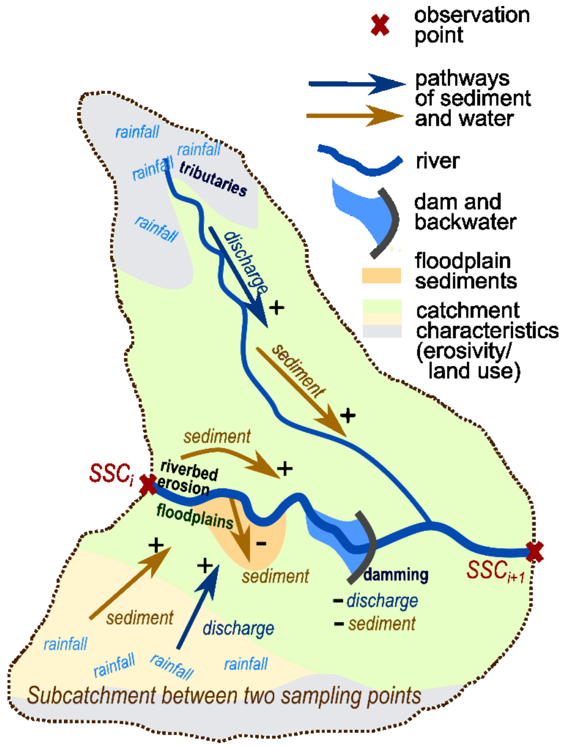
Discharge



Study area; (1) sampling sites and (2) rainfall-runoff model
Source: Wolf et al. UNDER REVIEW

Suspended sediment transport today

Possible extension	Term	Purpose	Composition
Ext-I	$\left(\alpha_Q \cdot Q_{i+1}^{\beta_Q} - \alpha_Q \cdot Q_i^{\beta_Q}\right) \cdot p_{rkm}$	Scaling discharge related transport processes over river section	Multiplication
Ext-II	$p_d \cdot \alpha_d$ (1) $p_d \cdot (Q_{i+1} - Q_i) \cdot \alpha_d$ (2)	Sediment deposit due to damming	Subtraction
Ext-III	$p_t \cdot p_r \cdot a_t$ (1) $p_t \cdot p_{EROS} \cdot p_r \cdot a_t$ (2)	Sediment entry by tributaries	Addition
Ext-IV	$p_{EROS} \cdot \left(\frac{p_{rkm}}{p_{subc}}\right) \cdot p_r \cdot a_{subc}$ (1) $p_{EROS} \cdot p_{subc} \cdot p_r \cdot a_{subc}$ (2)	Sediment entry due to hillslope erosion	Addition
Ext-V	$p_{rkm} \cdot \frac{Q_i}{Q_{i+1}} \cdot a_{rkm}$ (1) $p_{rkm} \cdot (Q_{i+1} - Q_i) \cdot a_{rkm}$ (2)	Riverbed erosion or floodplain deposition	Addition or Subtraction



$$p_{rkm} = \frac{\Delta_{rkm}}{rkm_{total}}$$

$$p_{subc} = \frac{\Delta_{Area,subc}}{Area_{total}}$$

$$p_t = \frac{\sum MQ_{Tributaries}}{MQ_{local}}$$

$$p_d = \frac{rkm_{dammed}}{\Delta_{rkm}}$$

$$p_r = \sum Rainfall, 3d$$

$$p_{EROS} = \overline{RUSLE_{Subc}}$$

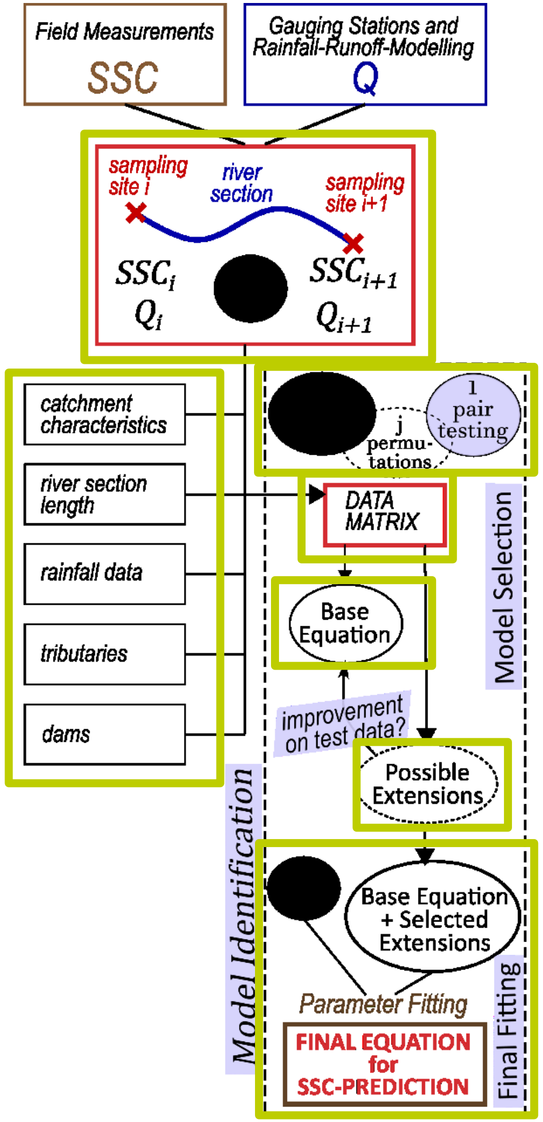
(Panagos et al 2020)

or

$$p_{EROS} = \overline{GLOSEM_{Subc}}$$

(Borelli et al. 2013)

Suspended sediment transport today



$$SSC_{i+1} = SSC_i + \left(\alpha_Q \cdot Q_2^{\beta_Q} - \alpha_Q \cdot Q_1^{\beta_Q}\right) \cdot p_{rkm} - p_d \cdot \alpha_d + p_{rkm} \cdot \frac{Q_i}{Q_{i+1}} \cdot a_{rkm}$$

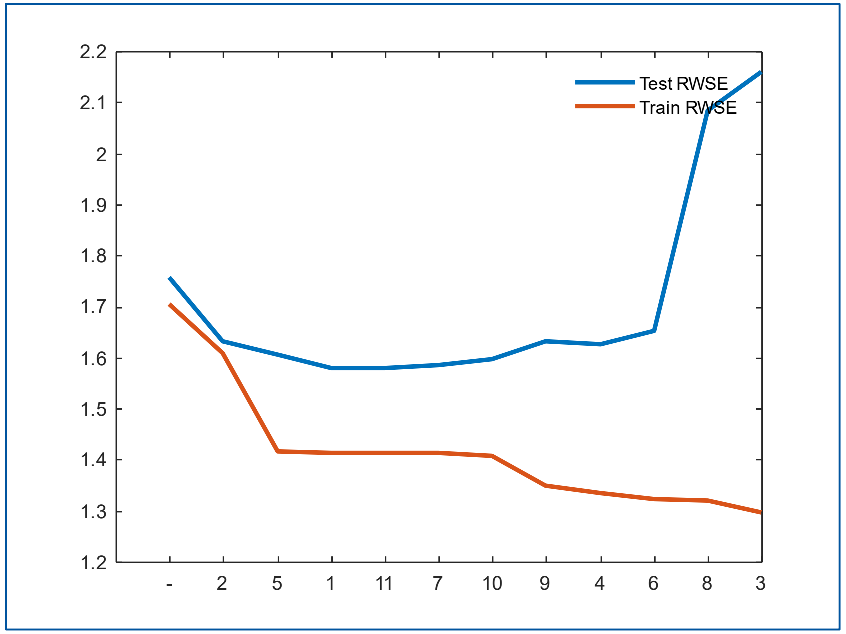
With:

$\alpha_Q = 39085.756$

$\beta_Q = 9.17E\text{-}06$

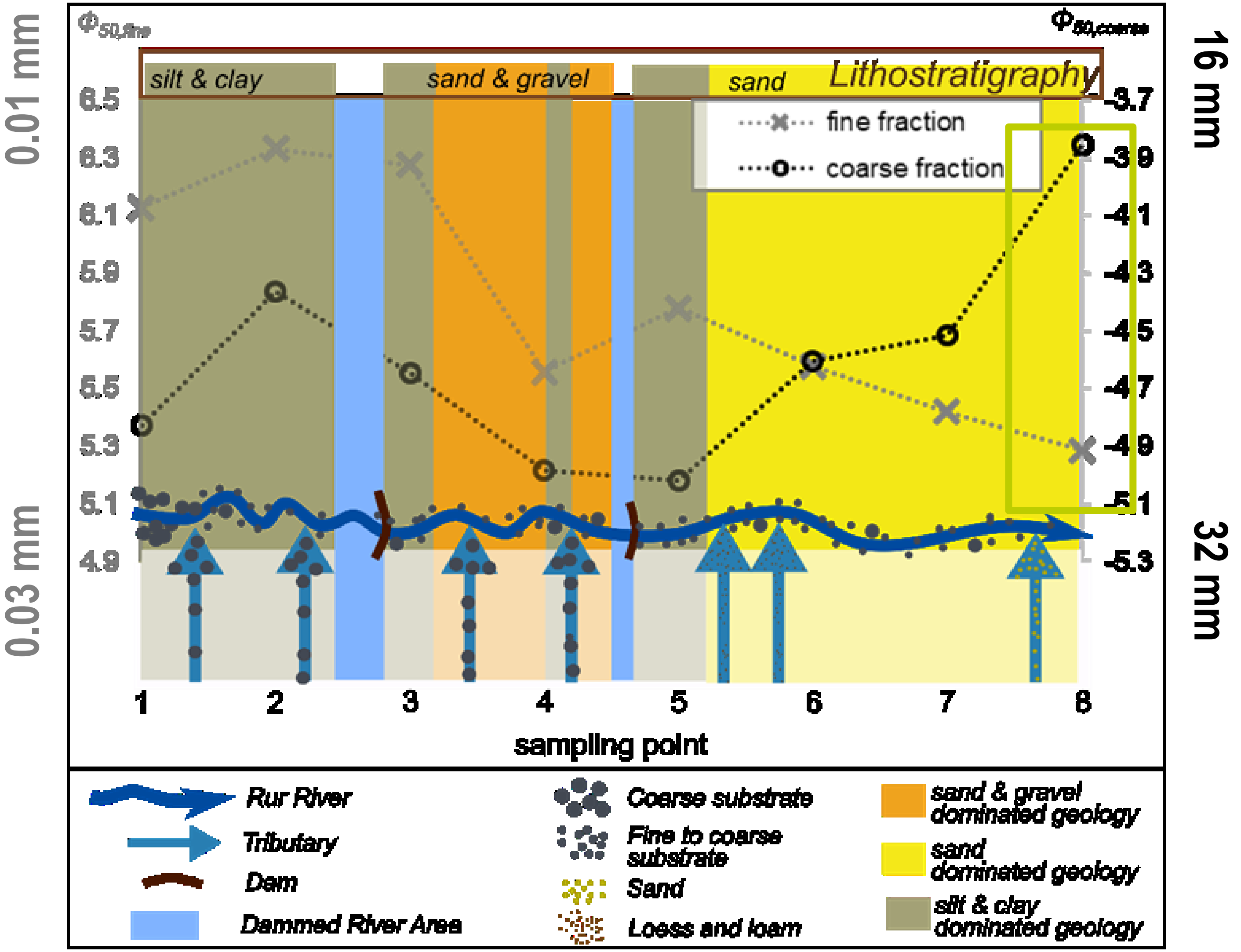
$\alpha_d = 0.9519$

$a_{rkm} = -0.2186$

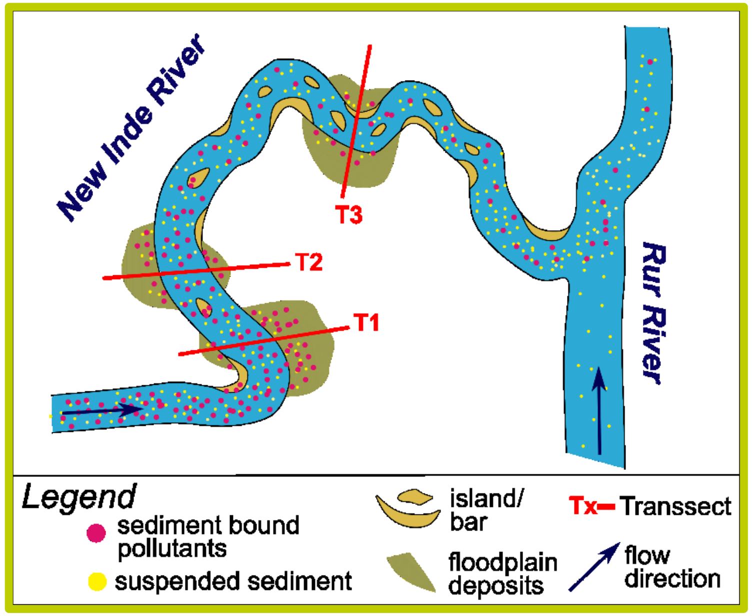


Wolf et al. UNDER REVIEW

Impact of the Rur dam - Riverbed



Source: Wolf et al. 2022



Source: Schulte et al. UNDER CONSIDERATION