Geomorphological alteration of urban rivers assessed by hydrological modelling

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1| Context and objectives

3 catchments located within the Seine river basin

Aulne (34 km²)

Mérantaise (20 km²)

Morbras (51 km²)

1| Context and objectives

Incision/widening marks on the Mérantaise (below) and the Morbras (right) ►

	Comparison of 2015 Xsections to...	Incision (m)		Widening (m)	
		Mean	Max	Mean	Max
Mérantaise	1980 Xsections	0.41	1.26	1.31	4.91
	Regional model	0.11	-	0.51	-
Morbras	1964 Xsections	0.39	1.05	0.75	3.10
	Regional model	0.43	0.58	0.98	2.50
Aulne		-	-	-	-

Comparison of the Mérantaise width and depth in 1884/1907, 1980 and 2015 in two close locations

2| Methods

Climate forcing (1959-2018)

Evolution of TIA

Long-term streamflow time series (1959-2018)

2| Methods

Climate forcing (1959-2018)

Hydrological model:
MU5H

$$\{\theta\} = \{\theta_{urb}, \theta_{nourb}\}$$

Estimated by calibration using
observed rainfall-runoff time series
(2007-2018)

Long-term streamflow time series (1959-2018)

Impact of urbanization on
competent flow

2| Methods

2.1 | Climate forcing and land cover evolution

Required data	Source	Time period
Precipitation (hourly)	SAFRAN (Vidal et al., 2010; 8 km resolution)	1959-2018
Potential evapotranspiration (hourly)		
Land cover (yearly)	LGP (land cover, polygons) and CORINE database (<u>land cover</u> at 100 m + <u>imperviousness</u> at 20 m)	Mérantaise: 1900-2015 Morbras: 1949-2015 Aulne: 1990-2015
Discharge (hourly)	LGP + INRAE + CD94	Morbras: 2007-2018 Aulne, Mérantaise: 2011-2018

2.2 | TIA time series: Recipe

Step 1: Estimate CPD from CORINE and LGP databases

2| Methods

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2.2 | TIA time series: Recipe

Step 1: Estimate CPD from CORINE and LGP databases

Step 2: Estimate TIA using: $TIA (\%) = 68.5 \left(1 - \sqrt{1 - \frac{CPD(\%)}{100}} \right)$

Step 3: Correct the estimations of TIA using the observed TIA for the year 2006

2| Methods

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- Step 4: Interpolation and extrapolation

2| Methods

2.3 | Hydrological model MU5H

Parameters

$I_{\max}$, θ_1 , θ_3 : Reservoir capacities (mm)
 θ_2 : Potential exchange parameter (mm)
 θ_4 : Base time of unit hydrographs (h)

2| Methods

2.3 | Hydrological model MU5H

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- I_{max} , θ_1 , θ_3 : Reservoir capacities (mm)
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- θ_5 : Quick-flow/slow-flow split parameter (-)

Mean event RR function of SMAR-50 for the least and most urbanized cases

Saadi et al. (2020, WRR)

2| Methods

2.3 | Hydrological model MU5H

Parameters

- I_{max} , θ_1 , θ_3 : Reservoir capacities (mm)
- θ_2 : Potential exchange parameter (mm)
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Coron et al. (2017); Edijatno et al. (1999);
Nash et Sutcliffe (1970); Gupta et al. (2009)

2| Methods

2.4 | Change in flow competence due to urbanization

3 periods of calibration

3 objective functions

Actual evolution of the catchment

$\theta_{urb} = \text{Observed yearly TIA}$

$\theta_{urb} = 0\%$

Catchment response if there were no urbanization (nonurbanized)

1. Q_{cr} is estimated from the nonurbanized simulation using

$$Q_{cr} = 0.6 \cdot \frac{1}{N} \cdot \sum_y Q_{d,max,y}(\theta_{urb} = 0) \quad \text{Pfaundler et al. (2011)}$$

2. Total competent flow (TCF) for the observed and simulated discharge

$$TCF_{ev} = \sum_{h \in ev} \max(Q_h - Q_{cr}, 0) \cdot \Delta t$$

Q_{sim} $\theta_{urb} = \text{Obs. TIA}$ Q_{sim} $\theta_{urb} = 0\%$ Q_{obs}

3. Relative change in TCF due to urbanization

$$\Delta_{rel} TCF_{ev,y} (\%) = 100 \frac{\sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = \text{Obs. TIA}) - \sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = 0\%)}{\sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = 0\%)}$$

3| Results

3.1 | Model calibration

3 periods of
calibration

3 objective
functions

= 9 optimal
parameter sets
 $\{\theta_1, \theta_2, \theta_3, \theta_4, \theta_5\}$

Acceptable calibration and control
performances!

3| Results

3.2 | Yearly evolution of catchment urbanization

Aulne @ Bullion

Mérantaise @ Châteaufort

Morbras @ Sucy-en-Brie

The Aulne illustrates the case of near-nonurbanized situation

The Mérantaise shows a “smooth” gradient of urbanization that reaches a significant level by the 1980s

The Morbras catchment shows a strong gradient of urbanization with TIA doubling in ~30 yrs (1960-1990)

3| Results

3.3 | Yearly evolution of TCF_{ev} vs. of urbanization

No substantial urbanization, no change in TCF_{ev}

Increased TCF_{ev} due to urbanization (44%-320%), but without a significant trend

Increase in TCF_{ev} for the Morbras catchment (-4%-96%), with a significant trend ($p < 0.001$)

3| Results

3.4 | Monthly evolution of TCF_{ev}

No substantial urbanization, no change in TCF_{ev}

No clear seasonality of the effect of urbanization on TCF_{ev}

A substantial effect of urbanization from late spring to fall

4| Conclusion

River	2015 X-sections compared to...	Incision (m)		Widening (m)	
		Mean	Max	Mean	Max
Mérantaise	1980 X-sections	0.41	1.26	1.31	4.91
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Mérantaise

Good model performances

Evidence for the effect of urbanization

But no clear trend!

Morbras

Model underestimates the competent flow

Evidence for the effect of urbanization

With a significant trend!

Thank you for your attention!

Questions?

References

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