Operation rules of the Vesdre reservoir revisited

Speaker: Benjamin Dewals

Co-authors: T. Cuvelier, P. Archambeau, S. Erpicum, M. Pirotton & Q. Louveaux

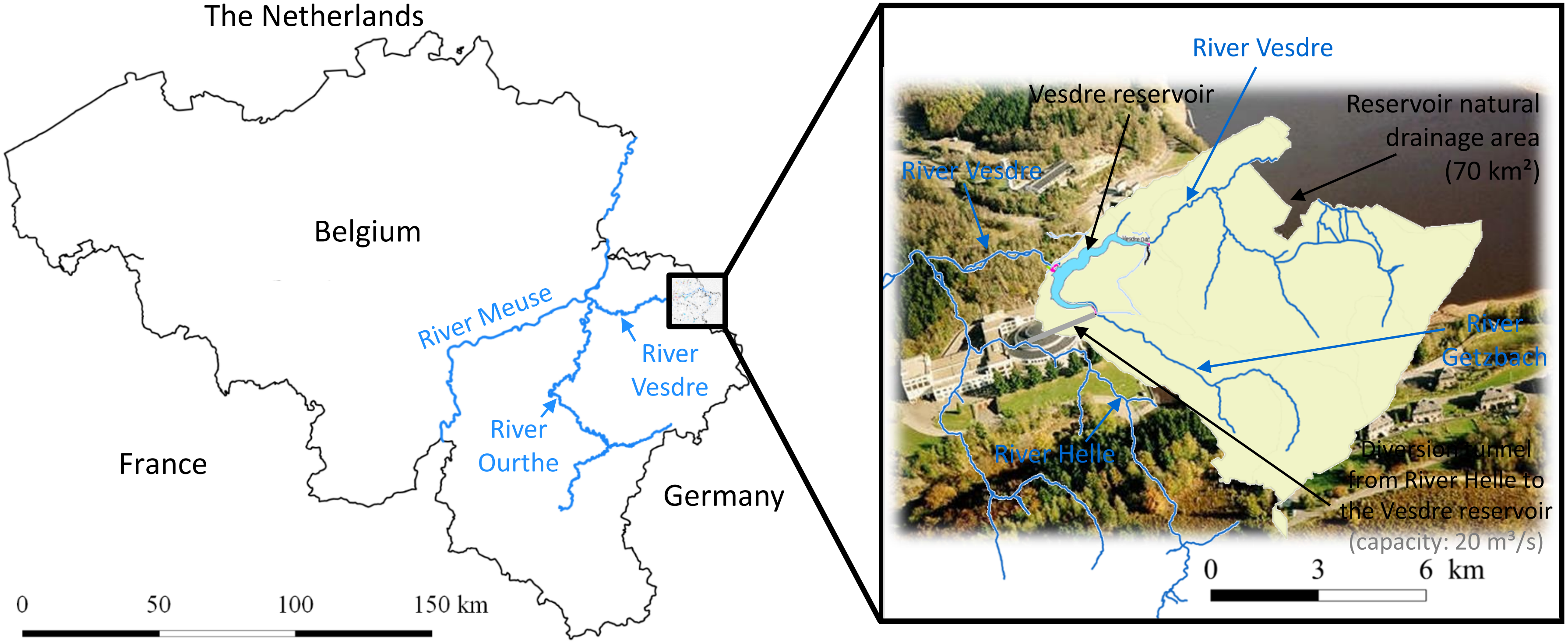
LIÈGE université

Wallonie

hece
Hydraulics in environmental and civil engineering

www.hece.ulg.ac.be

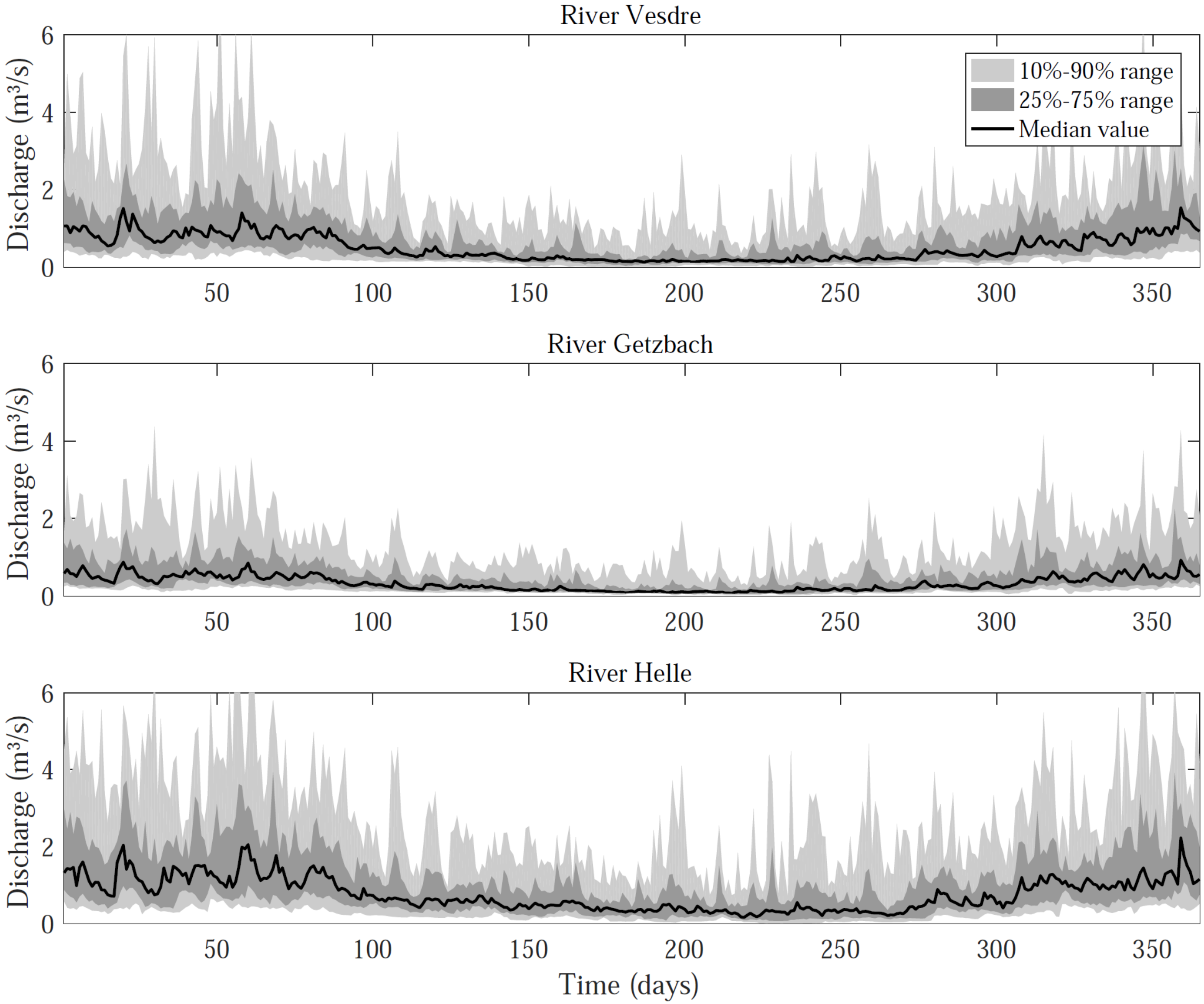
The Vesdre reservoir is primarily used for drinking water (55,000 m^3/day)



Total drainage area ~ 100+ km^2

Other purposes include flood and low-flow control, as well as hydropower (2.6 MW).

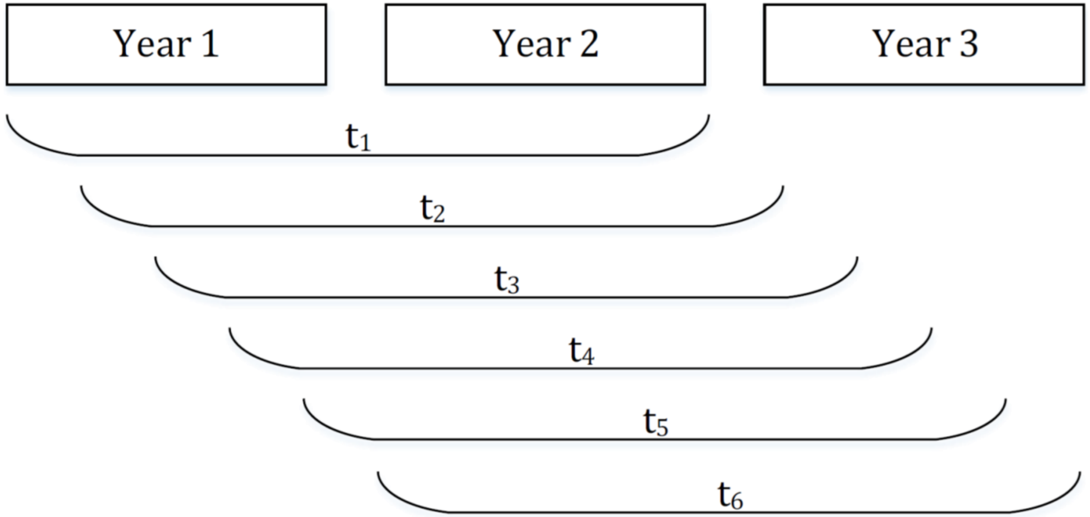
Available data include time series of daily inflows to the reservoir over the period 1995-2014



Problem formulation: *receding horizon control*

Find minimum reservoir level for each time step (e.g. daily or weekly), so that …

… whatever the reservoir inflows over the next two years, water supply can be ensured.



Moving time horizon

The computation of the rule curve is performed in three steps

1. Multiple scenarios of reservoir inflows are generated, to account for the uncertainty arising from natural variability in the flow.

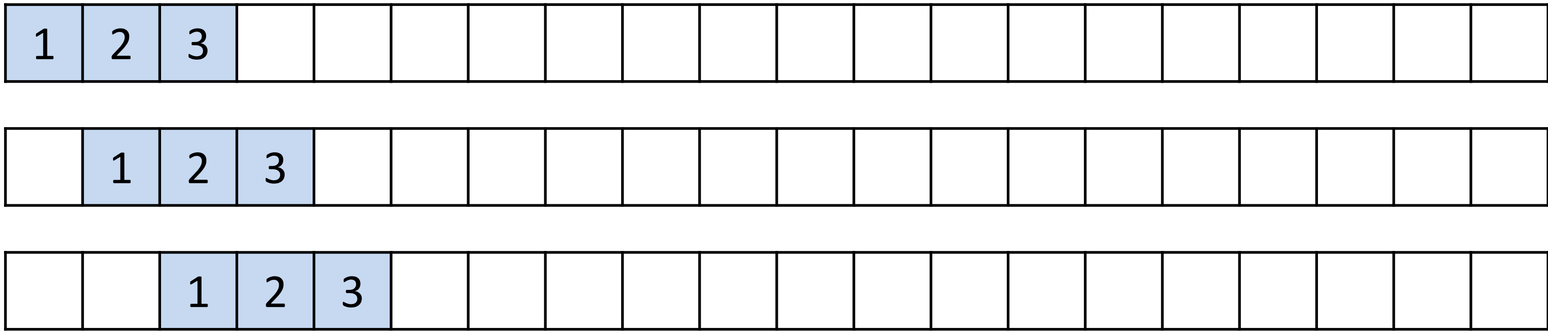
2. Each scenario is simulated independently, leading to scenario-specific minimum reservoir levels for each month.

3. The computed rule curve is determined as the upper envelope of the solutions obtained for the individual scenarios.

Two approaches were considered for generating the *scenarios*, defined by a set of inflow discharge

Merging

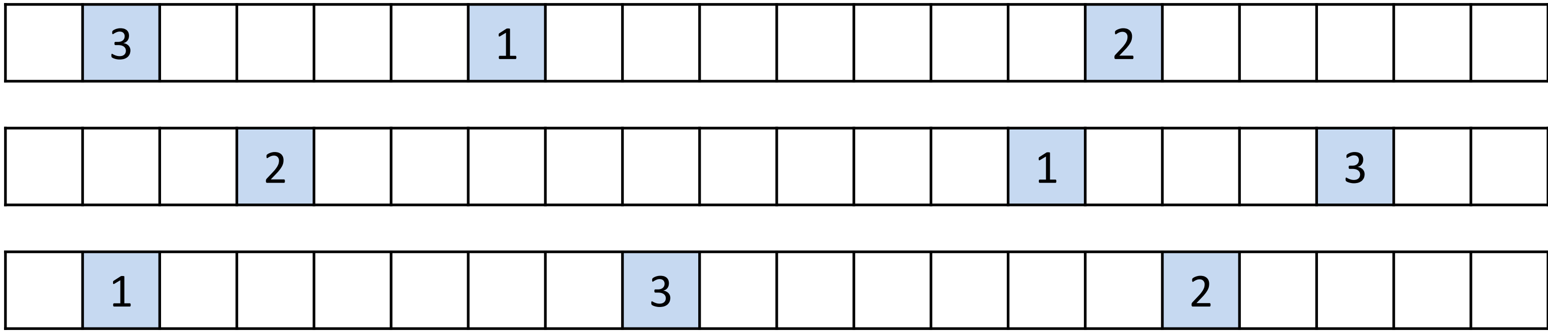
17 scenarios inter-annual correlations ✓



…

Mixing

8,000 scenarios inter-annual correlations ✗



…

This ends up with an optimization model, involving *linear* objective function and constraints

$$\min \quad \sum_t \mathbf{ruleStorage}_t$$

$$\text{subject to} \quad \mathbf{storage}_t^s \leq \mathbf{ruleStorage}_t \qquad \forall t, \forall s,$$

$$\mathbf{storage}_{t+1}^s = \mathbf{storage}_t^s - \mathbf{output}_t^s + \mathbf{input}_t^s \qquad \forall t, \forall s,$$

$$\mathbf{input}_t^s = \sum\nolimits_{r \in tributaries} flow_{t,r}^s + \sum\nolimits_{r \in diverted} \mathbf{diverted}_{t,r}^s \qquad \forall t, \forall s,$$

$$\mathbf{output}_t^s = drinkingWater_t + environmentalFlow_t + \mathbf{release}_t^s \qquad \forall t, \forall s,$$

$$minStorage \leq \mathbf{storage}_t^s \leq maxStorage \qquad \forall t, \forall s,$$

$$\mathbf{diverted}_{t,r}^s \leq maxDischarge_r \qquad \forall t, \forall s, \forall r \in diverted,$$

$$\mathbf{diverted}_{t,r}^s \leq flow_{t,r}^s - environmentalFlow_r \qquad \forall t, \forall s, \forall r \in diverted,$$

$$\mathbf{release}_t^s \leq penstockHydropower + bottomOutlet \qquad \forall t, \forall s,$$

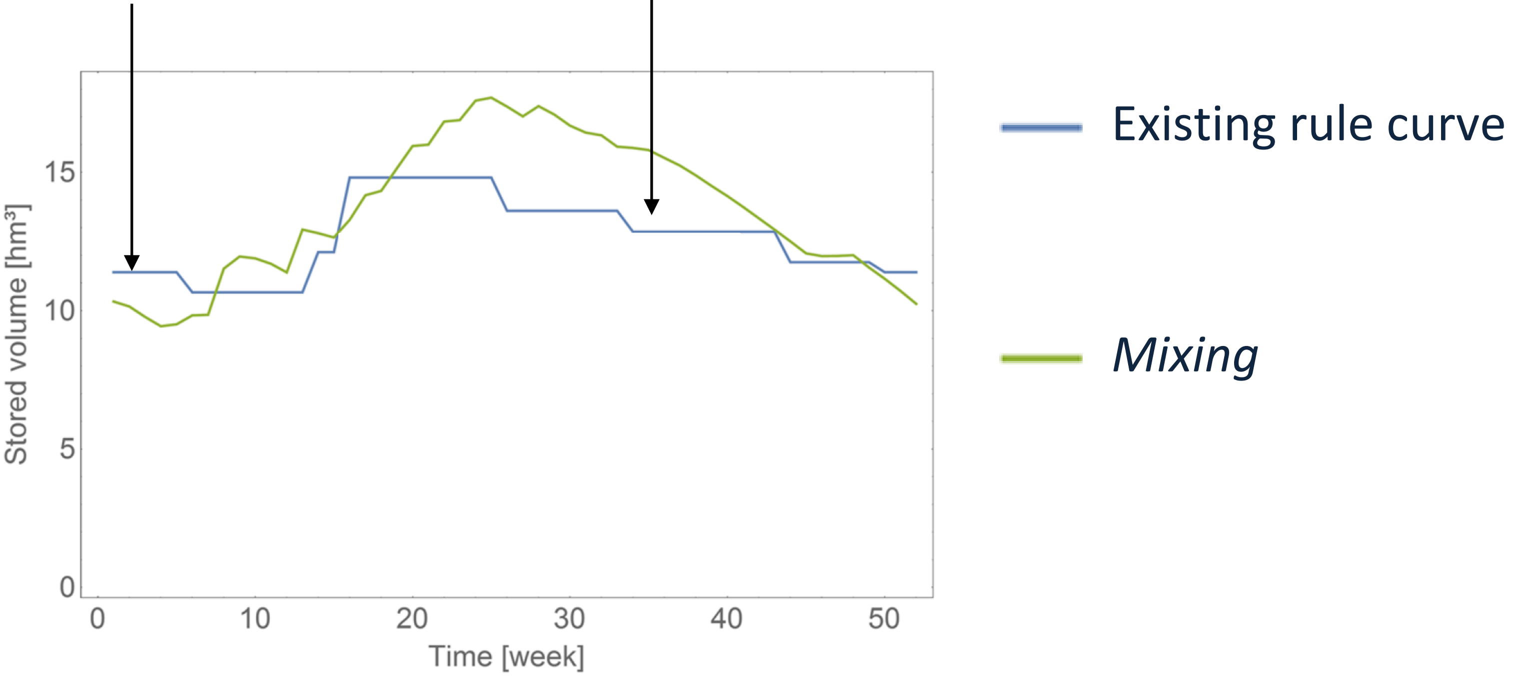
$$\mathbf{ruleStorage}_t \geq 0 \qquad \forall t,$$

$$\mathbf{storage}_t^s \geq 0, \quad \mathbf{output}_t^s \geq 0,$$

$$\mathbf{input}_t^s \geq 0, \quad \mathbf{release}_t^s \geq 0 \qquad \forall t, \forall s,$$

$$\mathbf{diverted}_{t,r}^s \geq 0 \qquad \forall t, \forall s, \forall r \in diverted.$$

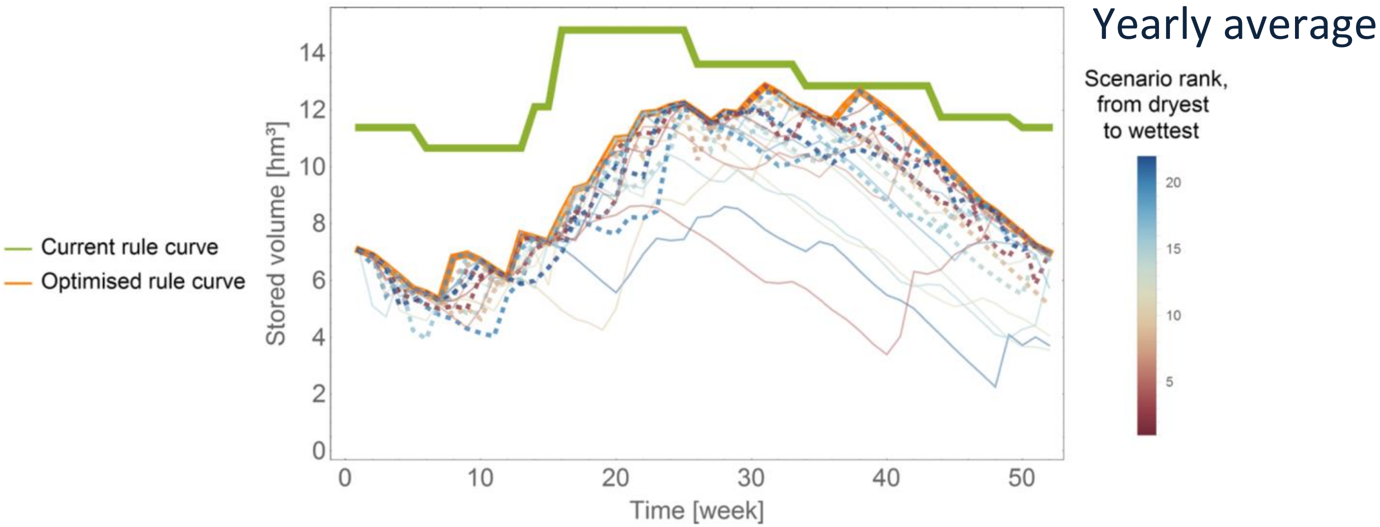
The computed rule curves strongly depend on how uncertainty is handled



Slightly "too safe"

"unsafe"

Support scenarios do not simply correspond to the driest years


Yearly average

Yearly average discharge (10^6 m³/day):

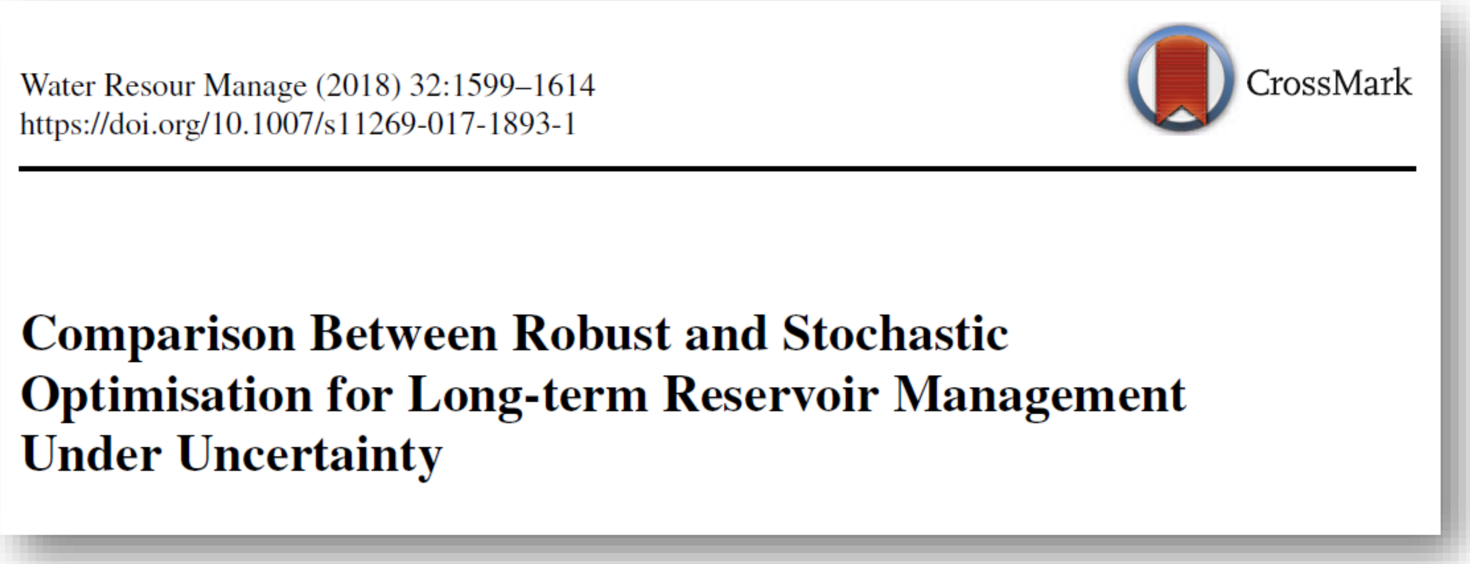
- *non-support* scenarios 0.857
- *support* scenarios 0.981

Instead, the years containing the driest months / seasons on record correspond mostly to the support scenarios

Conclusion

The historical rule curve of the Vesdre reservoir and the computed rule curve based on recent data show a similar overall pattern, despite some differences.

However, the computed rule curves strongly depend on how uncertainty in reservoir inflows is handled.



Water Resour Manage (2018) 32:1599–1614
https://doi.org/10.1007/s11269-017-1893-1

Comparison Between Robust and Stochastic Optimisation for Long-term Reservoir Management Under Uncertainty

Operation rules of the Vesdre reservoir revisited

Speaker: Benjamin Dewals

Co-authors: T. Cuvelier, P. Archambeau, S. Erpicum, M. Pirotton & Q. Louveaux