How many reservoirs should we build in France to maintain water availability under a changing climate?

Vazken Andréassian, Guillaume Thirel, Charles Perrin

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Why asking this question here in Vienna?

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Water wars

‘if the wars of this century were fought over oil, the wars of the next century will be fought over water‘

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Water wars – civil wars?

Building reservoirs to adapt to climate change?

- **Building reservoirs is one of the possibilities to adapt to the hydrological impact of climate change**

- **Decline of streamflow vs decline of water resources**

What part of natural flow can be considered a ‘water resource’?

- **Journalists & hydrologists very often use the expression ‘water resources’ as a synonym for ‘river / groundwater flow’.**

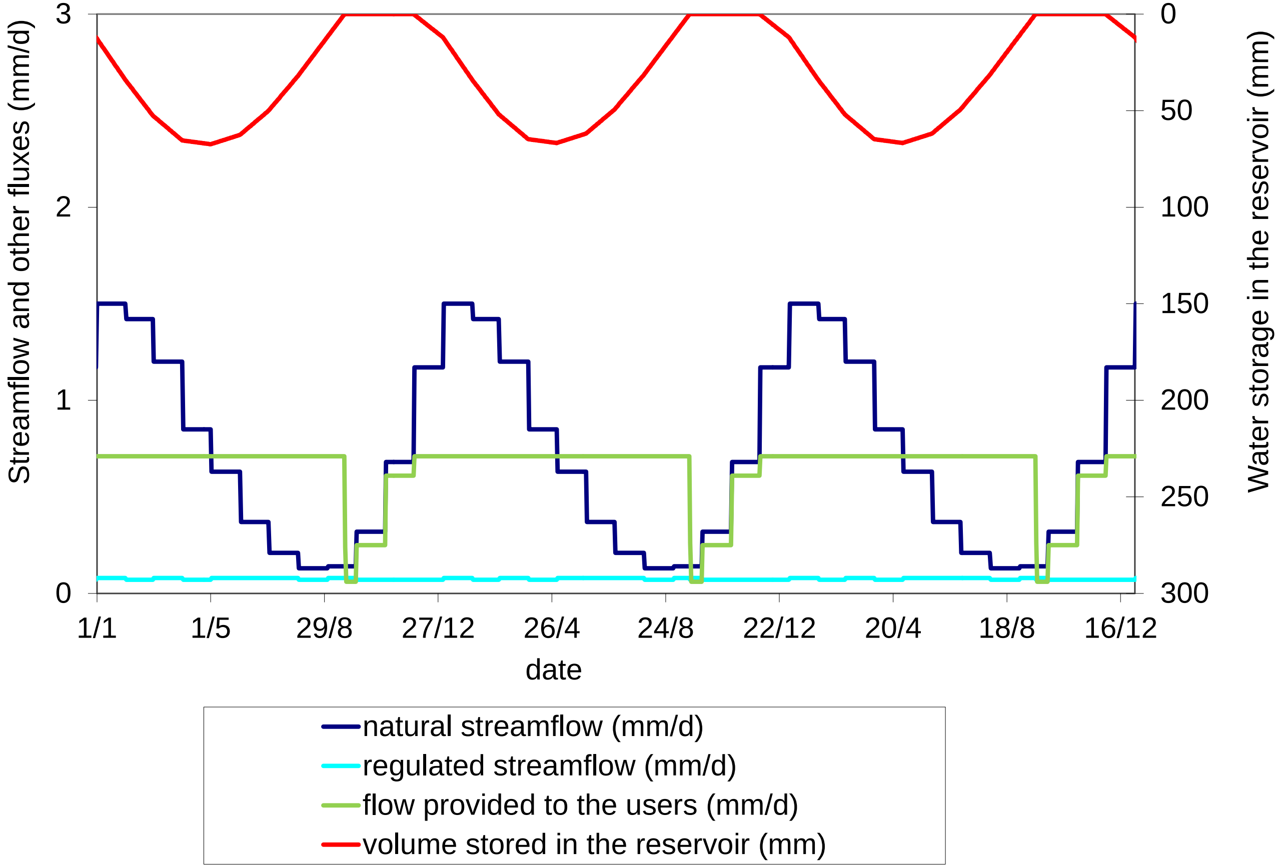
- **National and international databases often do the same (i.e. AQUASTAT-FAO, EUROSTAT, World Bank databases)**
  - ‘internal water resources’: totality of the ‘blue’ water flow originating on the territory of a country
  - ‘external water resources’: amount of water flowing to this country.

What part of natural flow can be considered a ‘water resource’?

- **These definitions imply that the entire water flow is a resource and we all know that it is not true**
- **Quantifying *water resources* is more complex than just quantifying *river/groundwater flow*. One must account for the flow-to-resource conversion efficiency:**
  - less that 100%
  - reduced by the irregularity of the given river regime
  - reduced by the amount of in-stream reserved flows
  - affected (positively or negatively) by the seasonality of the water demand
  - increased by the construction of reservoirs
  - potentially affected by climate change.

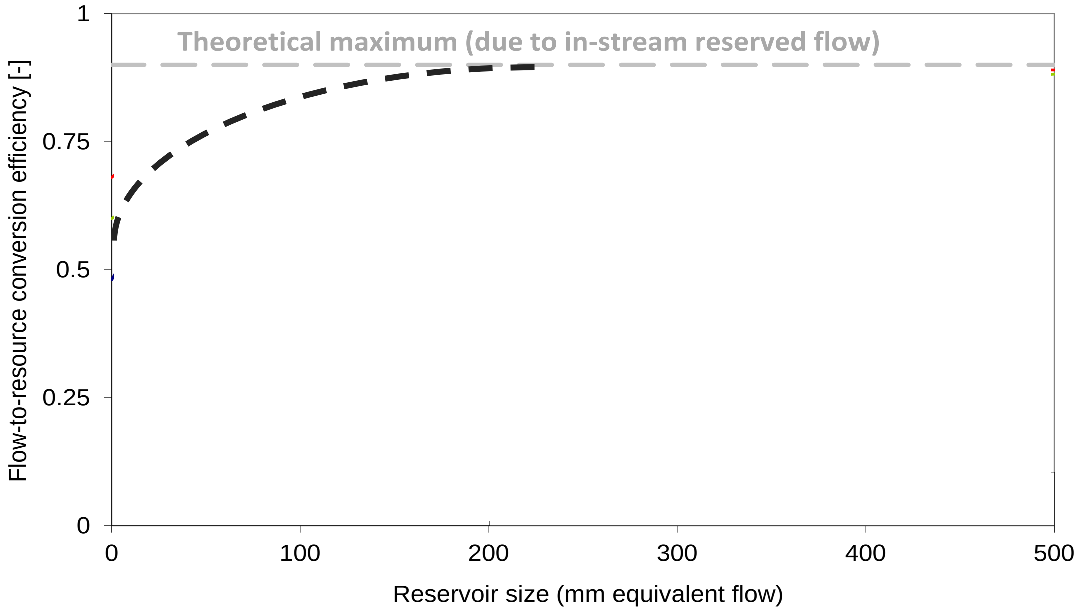
How do reservoirs affect the flow-to-resource conversion efficiency ?

- **Reservoirs allow turning a larger part of the natural river flow into a 'usable' water resource**

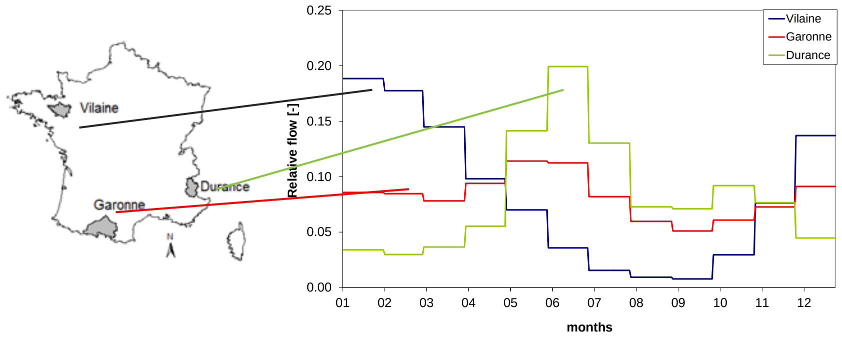


How do reservoirs affect the flow-to-resource conversion efficiency ?

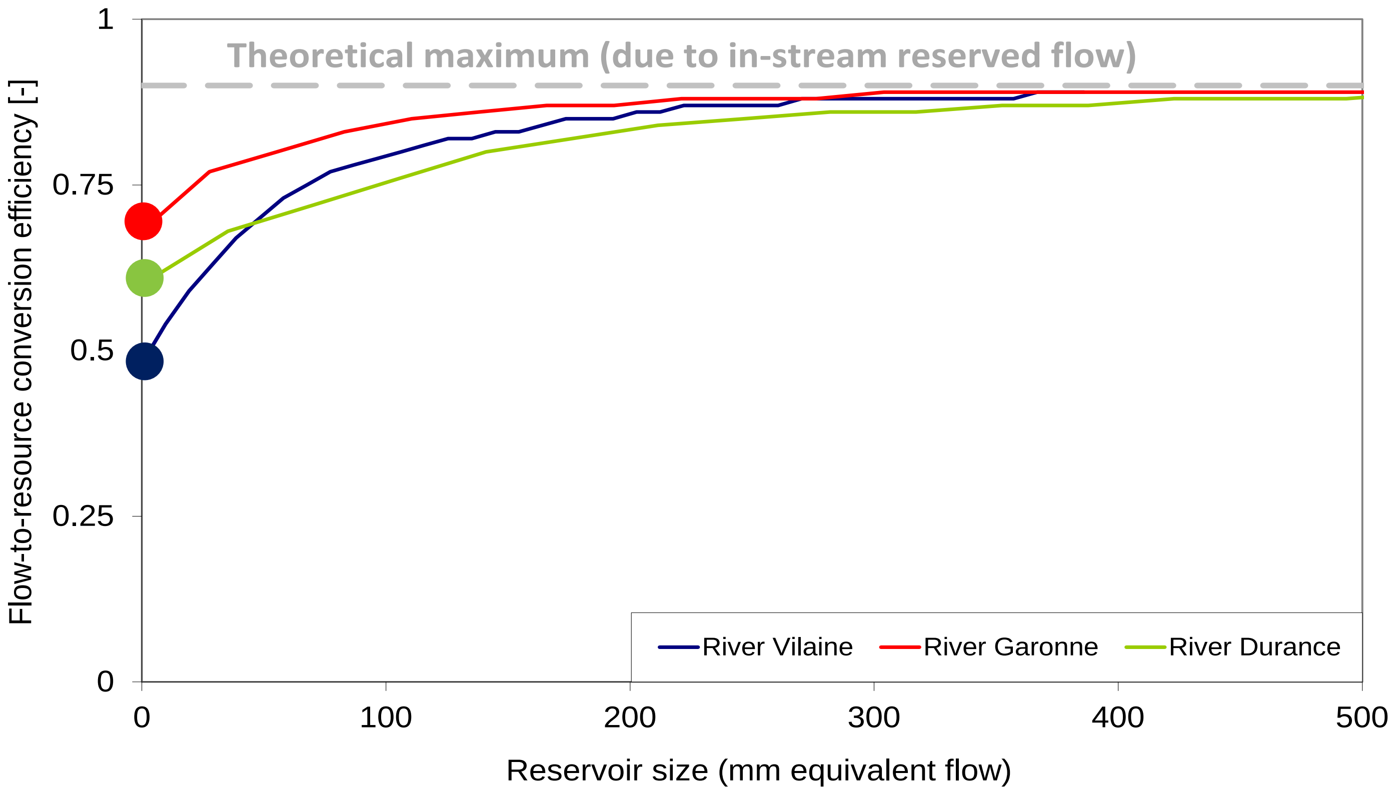
- **We can simulate the long-term effect of reservoirs on the flow-to-resource conversion efficiency:**
  - Based on long-term (> 30 years) daily flow records
  - Assuming a pattern of water demand



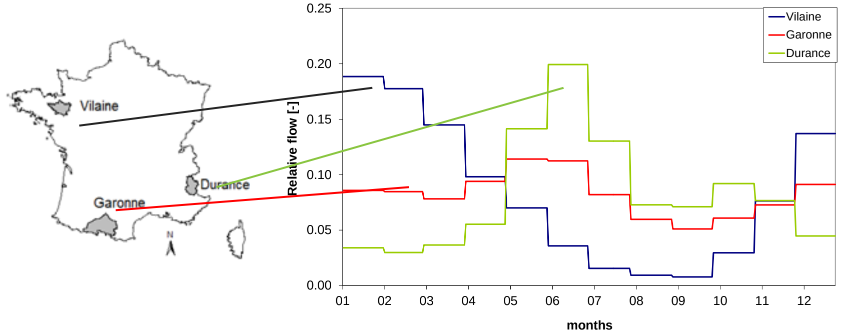
How do reservoirs affect the flow-to-resource conversion efficiency ?



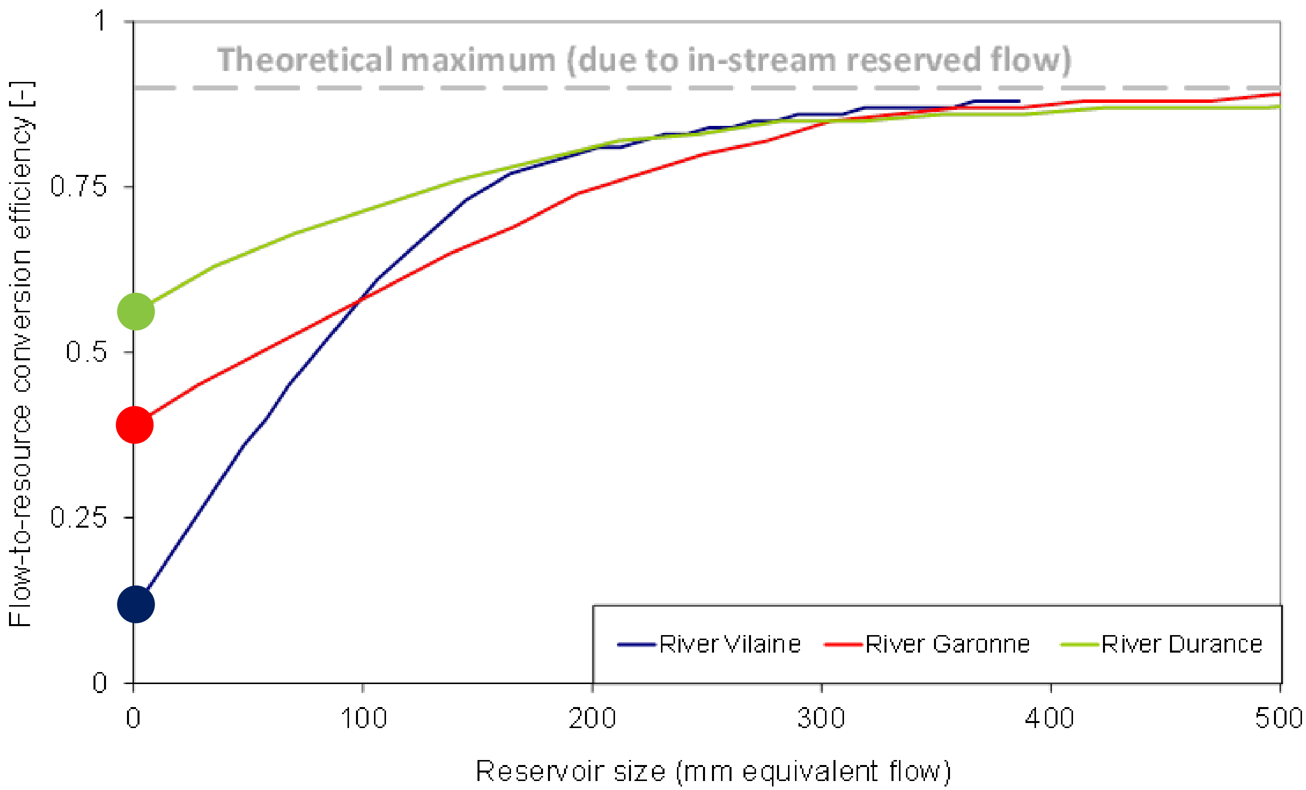
- **Constant ('urban') water demand**



How do reservoirs affect the flow-to-resource conversion efficiency ?



- **Seasonal (irrigation water demand**

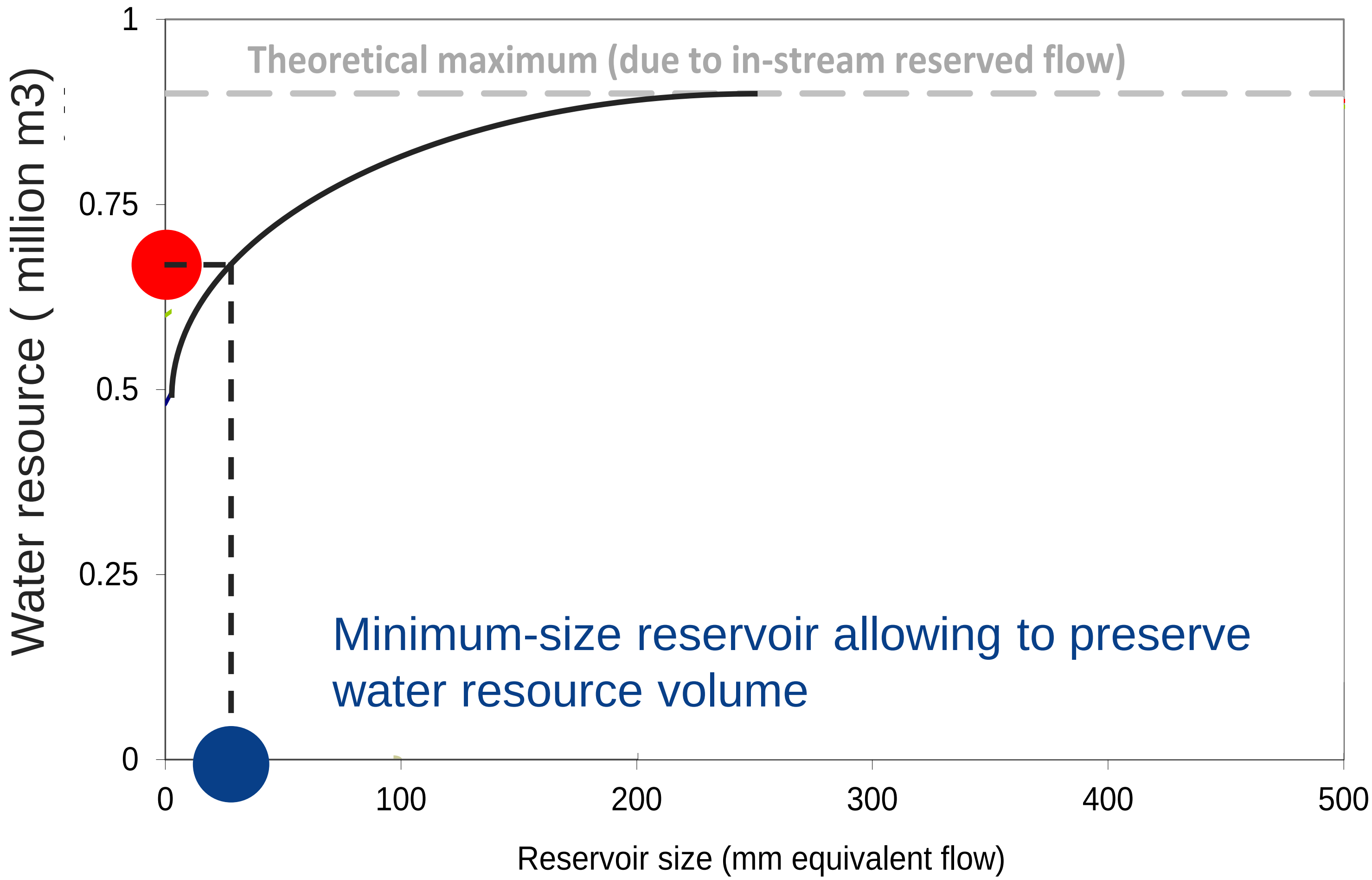


Synthesis

- **The flow-to-resource conversion efficiency:**
  - less that 100%
  - reduced by the irregularity of the given river regime
  - reduced by the amount of in-stream reserved flows
  - depends on the seasonality of the water demand

- **In the perspective of climate change:**
  - What would be the minimum reservoir size that would allow to mitigate the hydrological impact of climate change?

Maintaining water resources under a changing climate



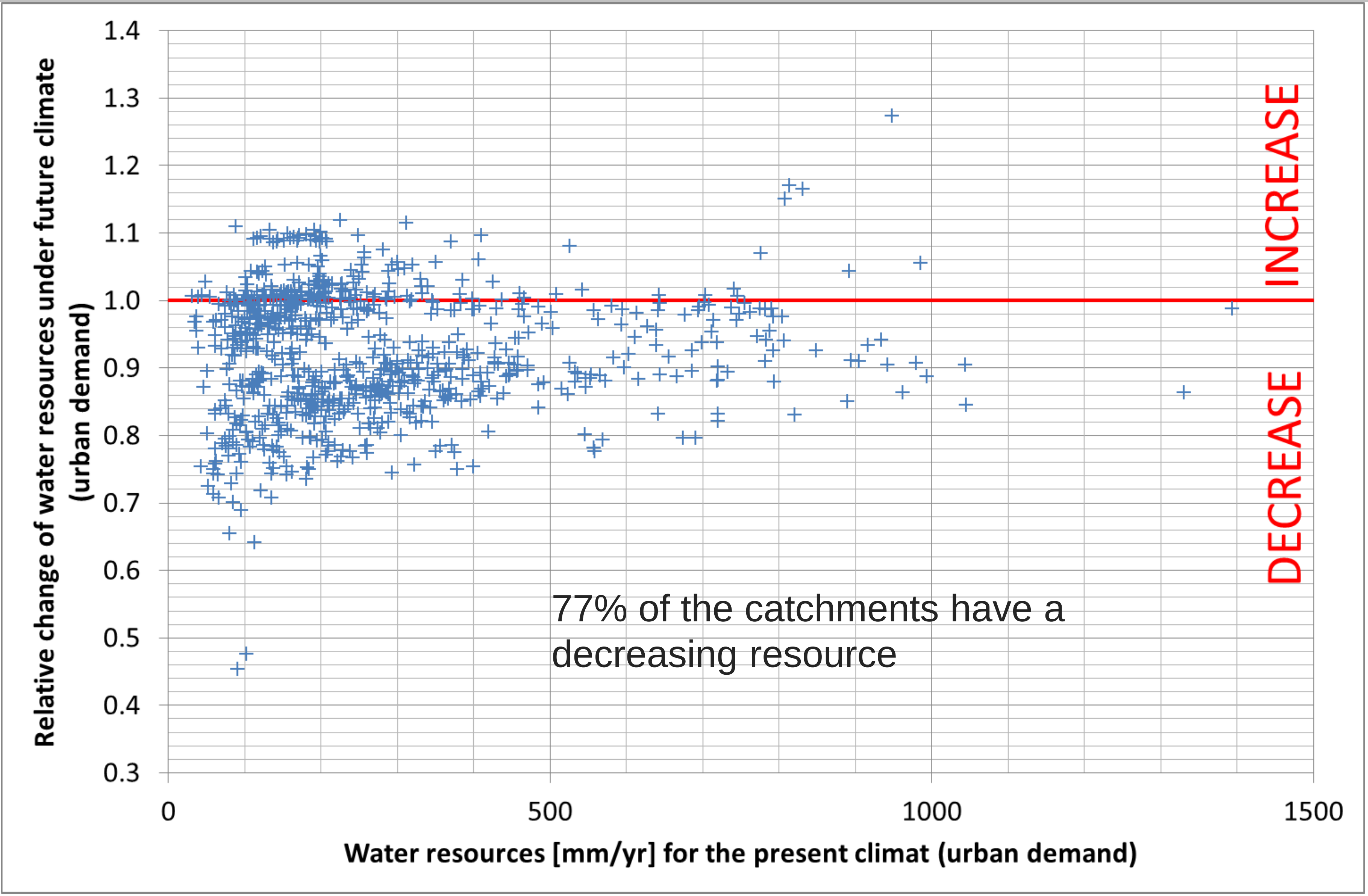
Building reservoirs to mitigate the hydrological impact of climate change?

- **CMIP5 (WRCP) projections were used**
  - Representative Concentration Pathway 8.5 (the worst case scenario)
  - CNRM/CERFACS Global Circulation Model (CNRM-CM5)
  - Downscaling method: Advanced Delta Change (van Pelt et al., 2012)
  - precipitation and temperature projections : 52 years of climate data whose statistics are representative of the 2071–2100 period
- **Dataset of 844 French catchments**
- **GR4J model to simulate flows under climate change**

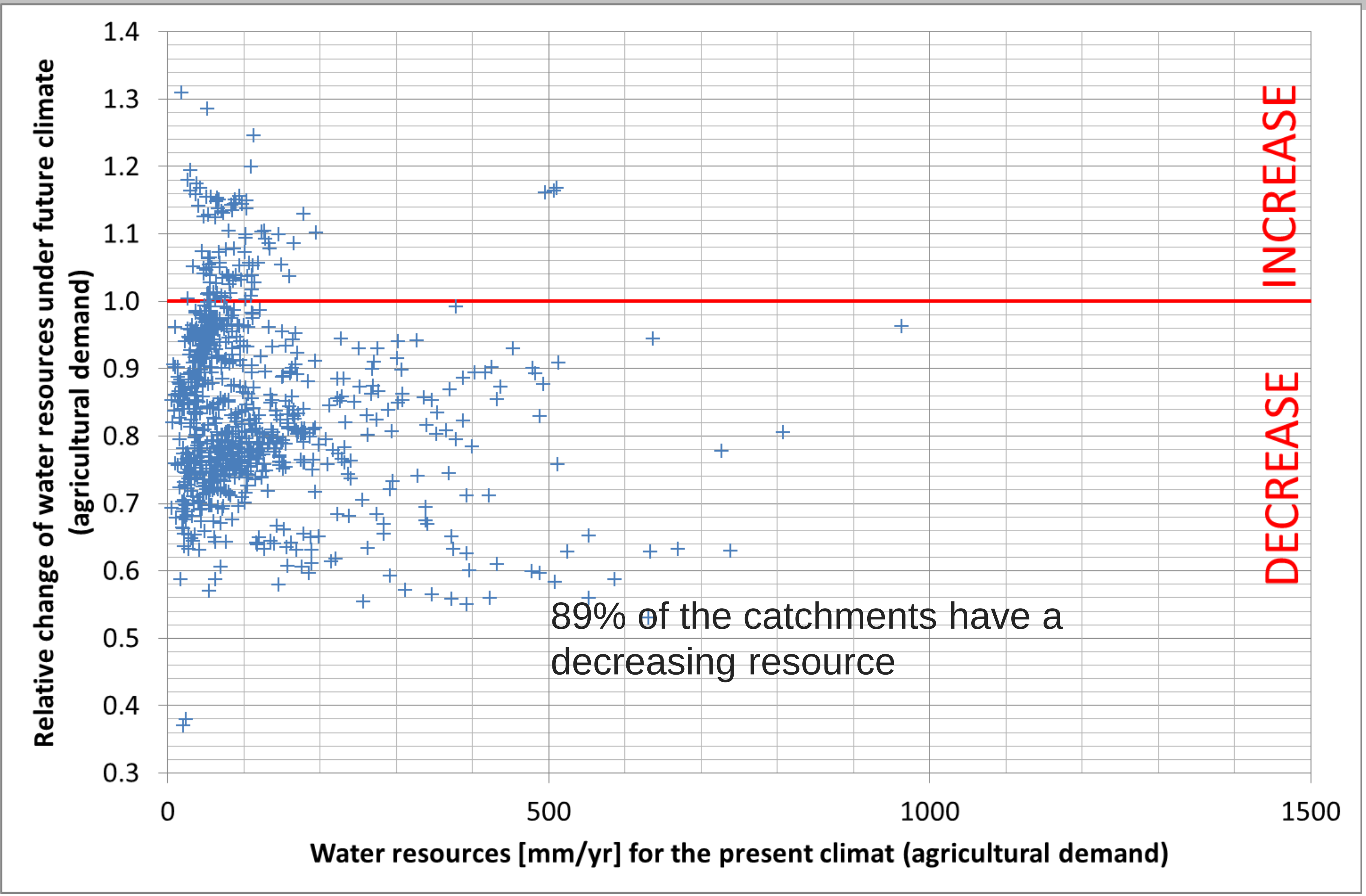
Van Pelt, S., J. Beersma, T. Buishand. 2012. Future changes in extreme precipitation in the Rhine basin based on global and regional climate model simulations. Hydrology and Earth System Sciences 16, 4517-4530.

Perrin, C., Michel, C. and Andréassian, V., 2003. Improvement of a parsimonious model for streamflow simulation. Journal of Hydrology, 279 : 275-289

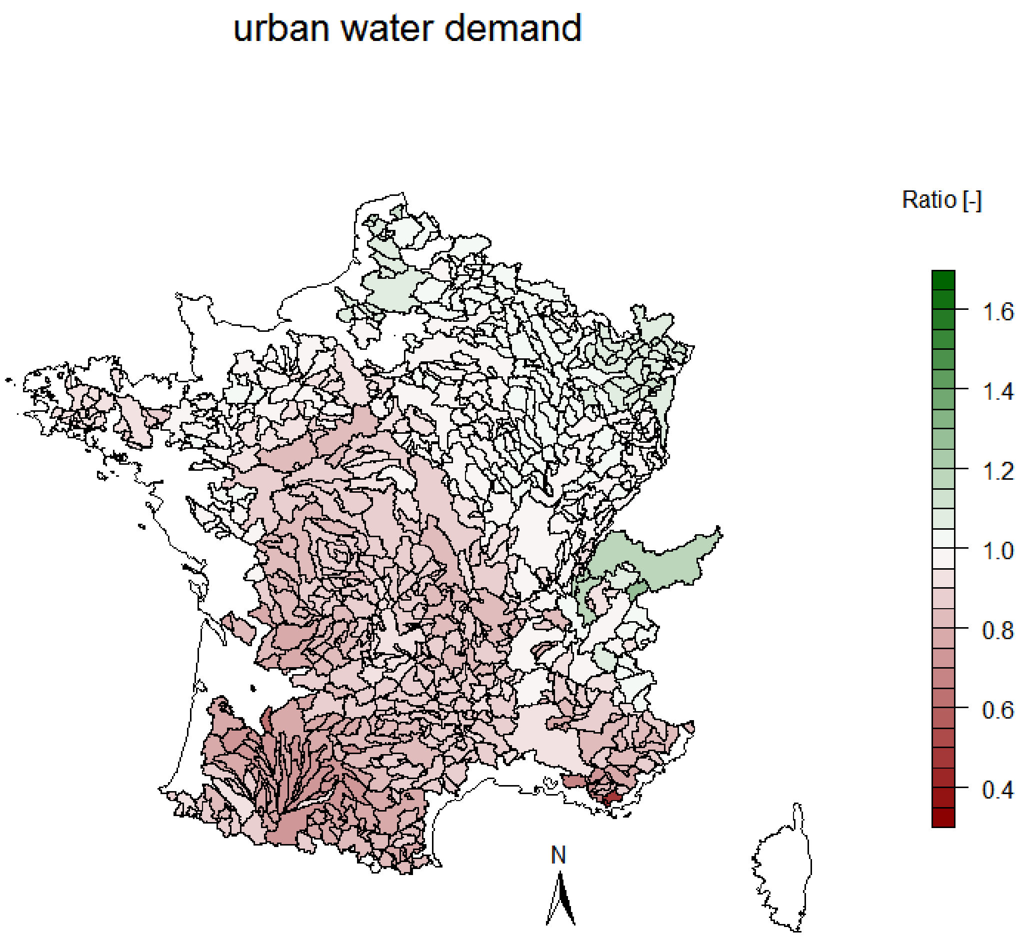
Results – urban demand



Results – agricultural demand

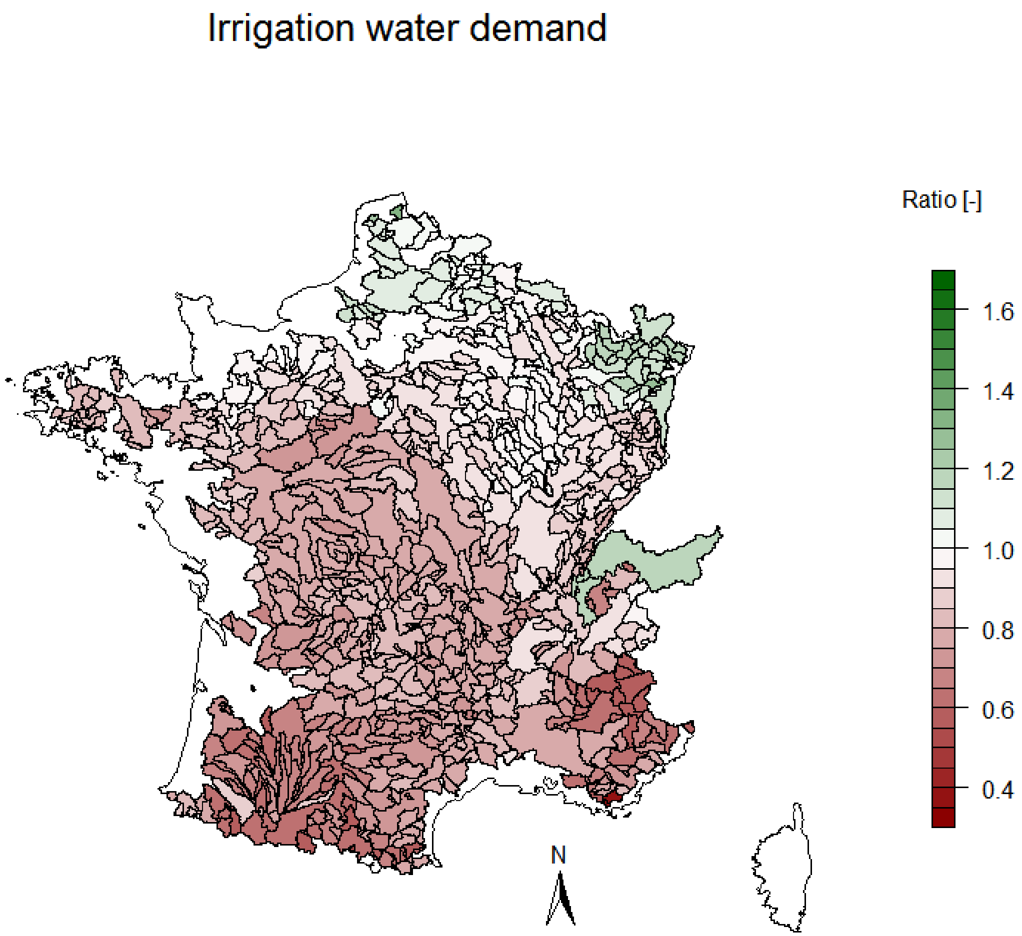


Results – urban demand



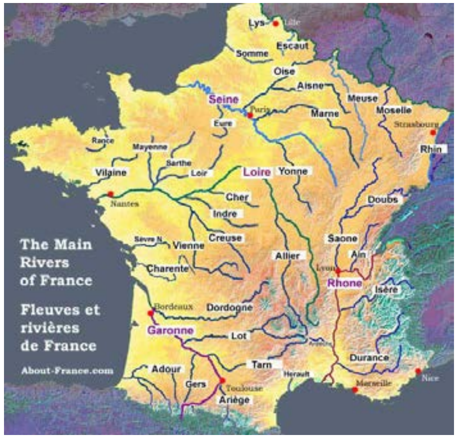
77% of the catchments have a decreasing resource

Results – agricultural demand



89% of the catchments have a decreasing resource

Conclusion : size of the reservoirs needed



- **Seine @ Paris (44 000 km²)**
  - Urban demand : 0.08 10^9 m^3
  - Irrigation demand : 0.1 10^9 m^3
- **Loire @ Montjean (110 000 km²)**
  - Urban demand : 2.6 10^9 m^3
  - Irrigation demand : 0.1 10^9 m^3
- **Rhône @ Beaucaire (96 000 km²)**
  - Urban demand : 1.8 10^9 m^3
  - Irrigation demand : 0.9 10^9 m^3
- **Garonne @ Mas d’Agenais (50 000 km²)**
  - Urban demand : 4.1 10^9 m^3
  - Irrigation demand : 1.0 10^9 m^3

Thank you