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# Cumulative impact of small reservoirs : a review of estimations and methods

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## Questions

- 1) What is the hydrologic cumulative impact of small reservoirs network ?
- 2) What is the state-of-the-art in matter of methods of cumulative impact estimations ?

A litterature review was perford to answer it.

## Small reservoirs

By storing water during wet season to support water uses (irrigation, livestock) during dry season, small reservoirs are considered as an adaptation technique to drought, uneven rainfall and climate change. Small reservoirs are also build to prevent flooding or to store sediments in check dams.

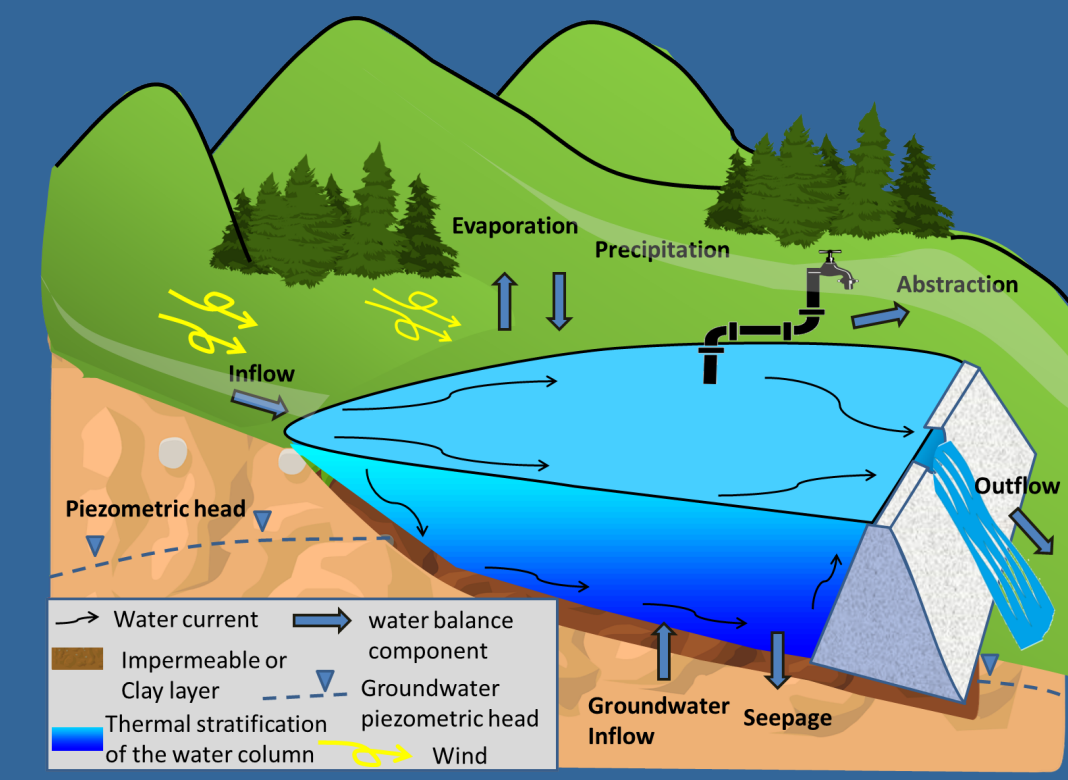


Figure 1 : main hydrological processes and human operations affecting the reservoir water balance

A small reservoir has a capacity lesser than 1 million m<sup>3</sup>. The local hydrological functioning of a small reservoir depends on hydrological processes as well as man operations (Fig. 1).

Figure 2 : map of an area of the Arrats River catchment showing in blue the small reservoirs



The number of small reservoirs has been increasing worldwide, especially in rural catchments of arid and semi arid regions. Small reservoir density can exceed 100 /km<sup>2</sup>, which may increase the water resource problem in both quantitative and qualitative ways.

## Estimated cumulative impacts

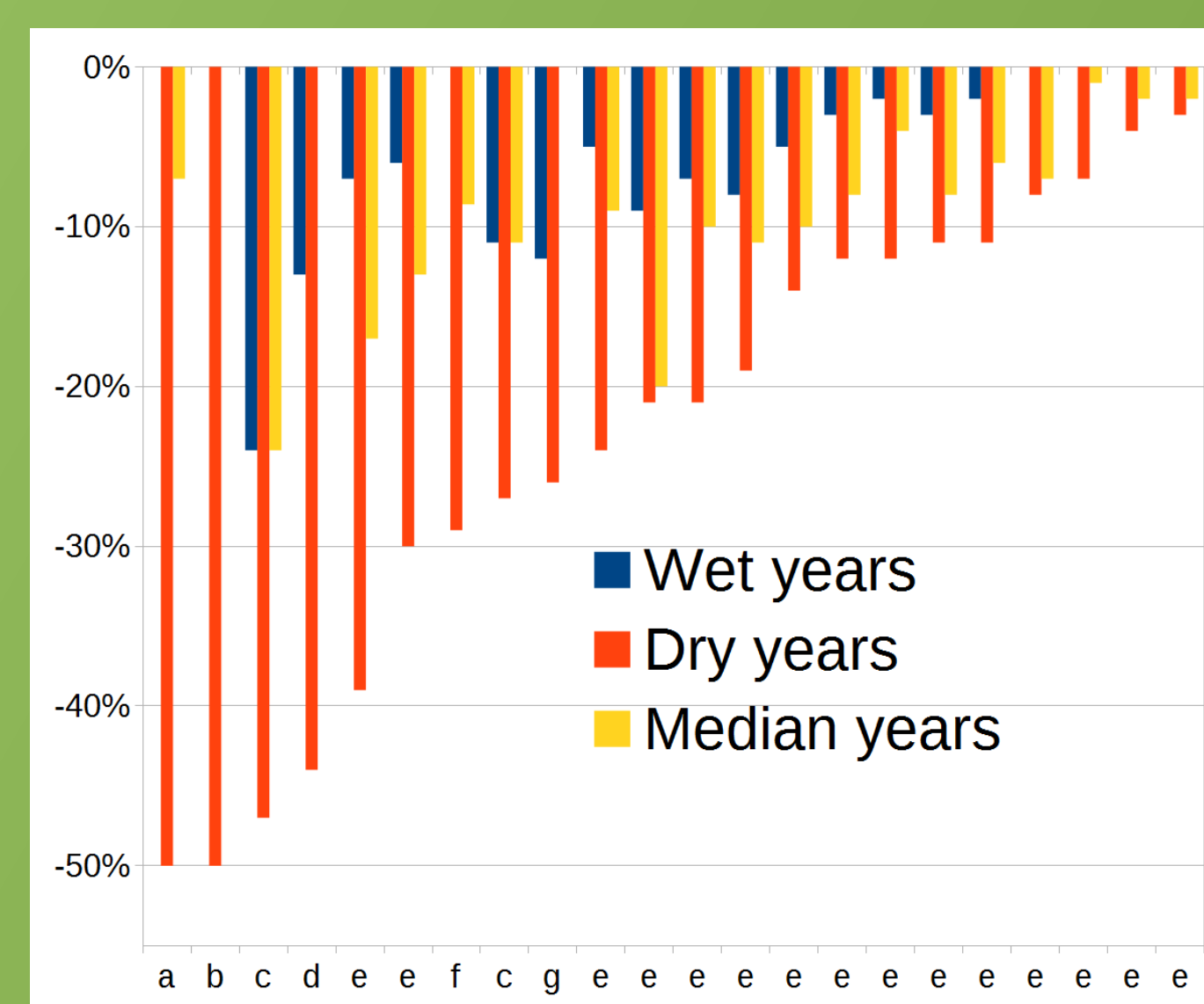


Figure 3 : Stream discharge decrease for wet, median and dry years. Every bar corresponds to a catchment for which the stream discharge decrease was estimated.

- Cumulative impact is mainly estimated in considering annual stream discharge
- Annual stream discharge decrease due to small reservoirs network (Fig. 3):  
Range: [0.2 %-36.0 %]  
Mean: 13.4 %
- For a given catchment, decrease varies :  
Higher decrease in wet year (Fig. 3)
- No simple relation between stream discharge decrease and reservoir network properties (number density, volume and surface density) (Fig. 5)

Figure 4 : Impact on the annual discharge decrease (colour scale on the right), as a reservoir cumulative impact, estimated from various catchments in different regions (Africa, America, Asia and Australia, see legend in plot (b) for the symbol of every of these regions) as a function of possible indicators: reservoir density expressed as number per square kilometre and as volume stored per square kilometre, annual precipitation, or specific discharge. Every point represents a catchment.

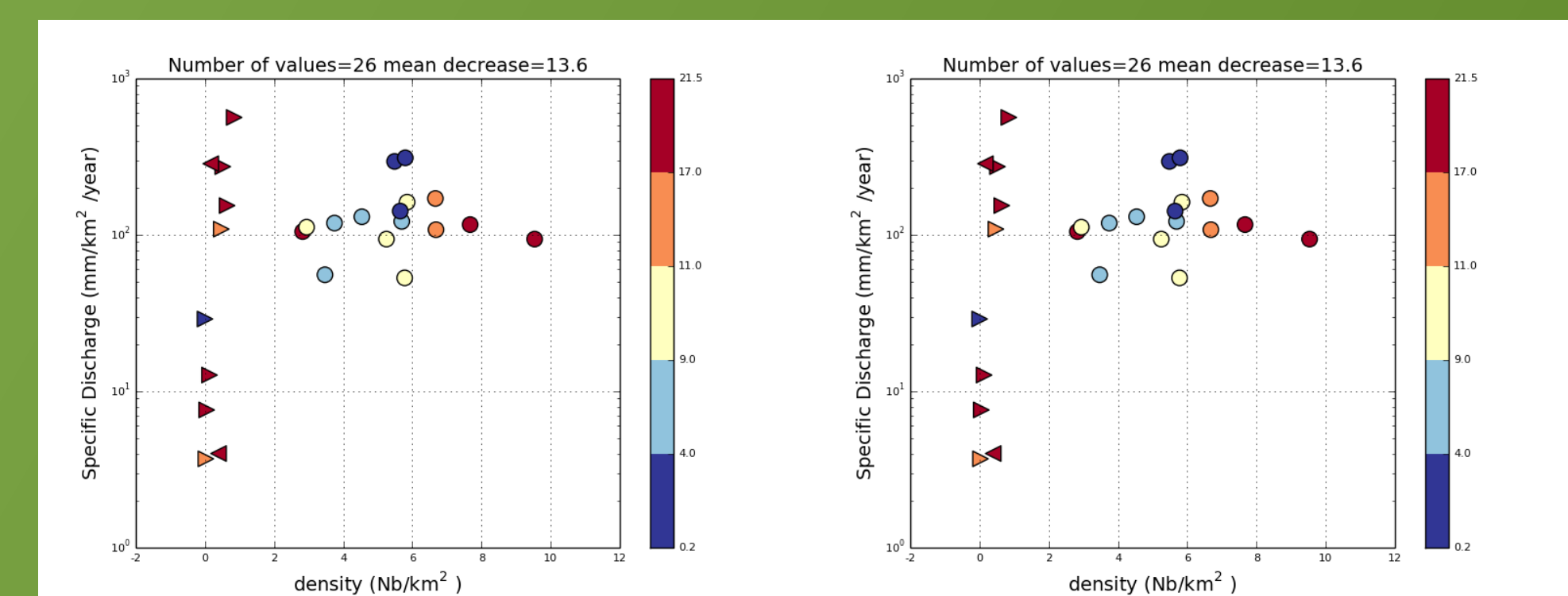


Figure 6 : Small reservoirs in a) France, b) Tunisia, c) Australia and d) India.

## Two main approaches for estimation

### 1- Exclusively data-based methods

- From observation of selected reservoirs to cumulative impacts estimation  
quantifying single reservoir functioning from the monitoring of a sample of reservoir and extrapolate the cumulative impact → cumulative impact is not the sum of single impact
- Statistical analyses of the observed discharge  
to connect the detected changes in the statistical properties of river discharge time series with the evolution of the reservoir network within the basin → need long time series ; difficulty to decipher the potential causes of stream flow changes
- Paired catchment  
quantifying the impact from a comparative analysis of stream flows monitored in two contrasted catchments, one with small reservoirs, the second one without small reservoirs → not appropriate for predictions of impact of new small reservoirs

### 2- Modelling approach

- Principle : Coupling of the small reservoir water balance model with a quantitative method to estimate stream inflow into the small reservoirs.
- 3 main types of reservoir network representation :
  - Aggregative
  - Statistical
  - Distributed

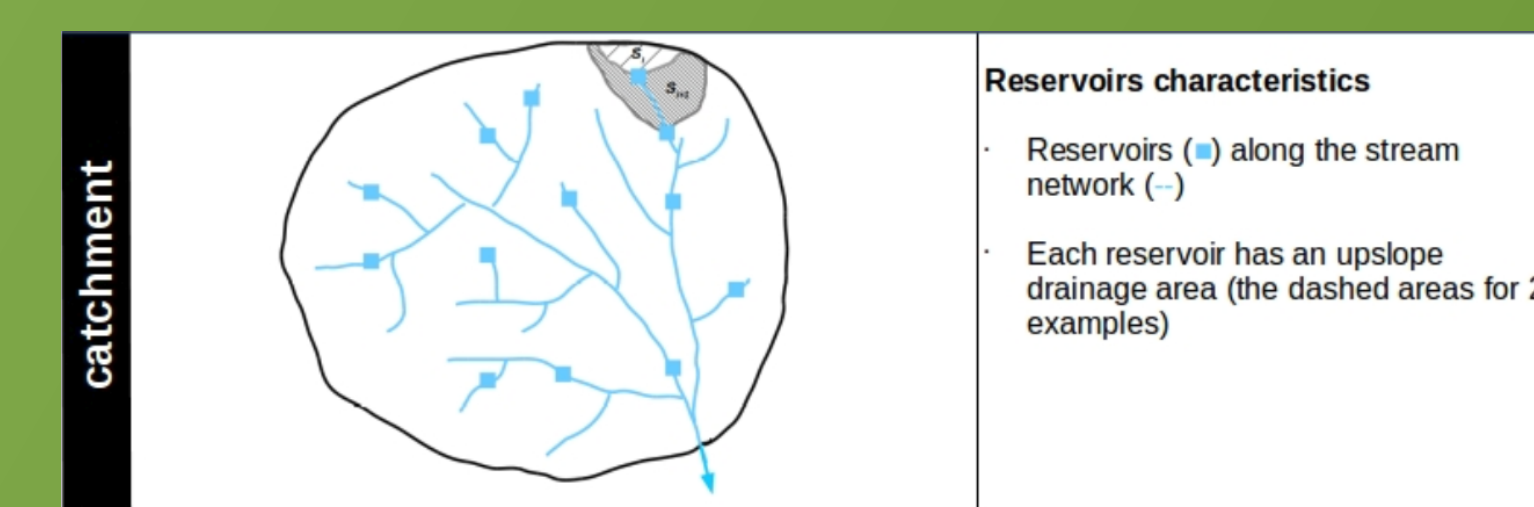


Figure 5 : Catchment and reservoir network to model (above). Spatial representation of reservoir network in models used to quantify cumulative hydrological impacts. (Right)

	Scheme	Principles
A		Reservoir network represented by an equivalent single reservoir  The simulated catchment discharge, $Q_{sim}$ is the sum of $n \times Q_{res}$ , the non-intercepted simulated stream discharge and $Q_{int}$ , the downstream flow from the equivalent reservoir simulated by the mass balance reservoir model. ( $Q_{int}$ is the catchment areal fraction of the cumulative upstream drainage area of all the reservoirs)
B		Reservoir network represented by classes of equivalent reservoirs. Each class corresponds to a given range of reservoir capacity.  $Q_{sim}$ , the catchment discharge, is distributed over each reservoir class by simple rules. The outflow from one reservoir class is propagated through the downstream classes by simple rules of cascading.
C		Each reservoir represented along with its upstream flow ( $Q_{up}$ ).  A single mass balance model, applied to each reservoir, simulated the down stream flow of the reservoir ( $Q_{down}$ ) which is propagated downstream through the stream network.

- Modelling is currently the most common approach. However, important issues are addressed.

## Current Issues

### Uncertainty

Review shows that the uncertainty in simulated impact may result from three main factors : i) reservoir characteristics, in particular reservoir drainage area, ii) water management estimation, especially abstraction estimation, and iii) spatial representation of reservoirs and iii)

### Small reservoir characteristics

Location, connexion to the river, capacity and bathymetric relationship are among the characteristic needed for cumulative impact estimation. Along with improvements in survey and remote sensing methods, one track to improve our capability of estimating small reservoir cumulative impacts relies on storing and sharing of information collected through operational surveys and scientific studies

### Abstraction estimations

Estimations of cumulative impact of small reservoirs are very sensitive to estimation of abstractions from reservoir. Two way to improve abstraction estimations :

- i) store and make available farmers declaration (abstraction volumes and occasionally the timing) to water management agencies or state services. Empirical relations relating the characteristics of reservoirs with crop or animal needs could be one way to estimate and spatialize the water abstraction from small reservoirs more accurately than the current simple and pragmatic methods.
- ii) take advantage of agronomic state-of-the art in terms of crop management strategies and models. Decision rule models are now available to simulate and predict tillage, sowing, fertilization, hoeing, irrigation, crop protection, and harvesting periods.

### Impact indicator

Simple indicators of cumulative impacts are needed by stakeholders and water management actors. From a scientific perspective, this operational need consists of first analysing whether cumulative impacts can be derived from properties of reservoir networks or others.

This work is drawn from the report of a joint scientific assessment requested by the French Ministry of the Environment, and supporter by ONEMA (now AFB), to collect useful information/knowledge and tools to provide local stakeholders with such indicators and methods to assess the cumulative impacts of small reservoirs. The full report is Carluer N, Babut M, Belliard J, Bernez I, Burger-Leenhardt D, Dorioz J, Douez O, Dufour D, Grimaldi C, Habets F, Le Bissonnais Y, Molénat J, Rollet A, Rosset V, Sauvage S, Usseglio-Polatera P, Leblanc B (2016) CUMULATIVE IMPACT OF RESERVOIRS ON THE AQUATIC ENVIRONMENT. Joint scientific assessment SUMMARY. Tech. rep., DOI <http://dx.doi.org/10.14758/SCIENT.ASSESSMENT.REPORT.05.2016>