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 perfored to answer it.

Small reservoirs

By storing water during wet season to support water uses (irrigation, livetsock) 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.

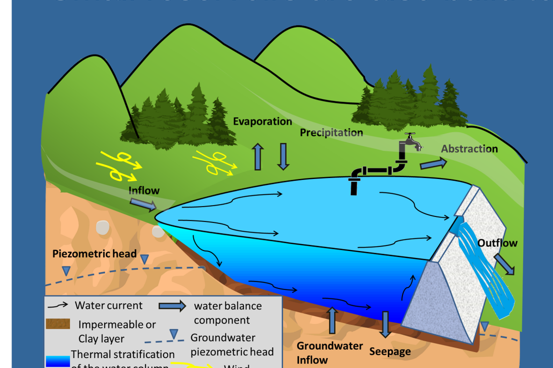
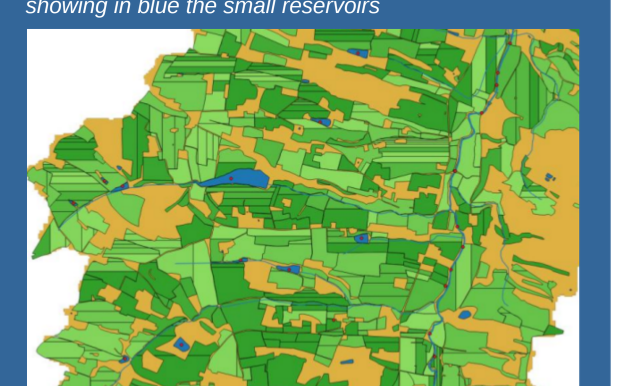


Figure 1 : main hydrological processes and human operations affecting the reservoir water balance

A small reservoir has a capacity lesser than 1 million m³. The local hydrological functionning 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 wolrdwide, especially in rural catchments of arid and semi arid regions. Small reservoir density can exceed 100 /km² , which may increase the water resource problem in both quantitative and qualitative ways.

Estimated cumulative impacts

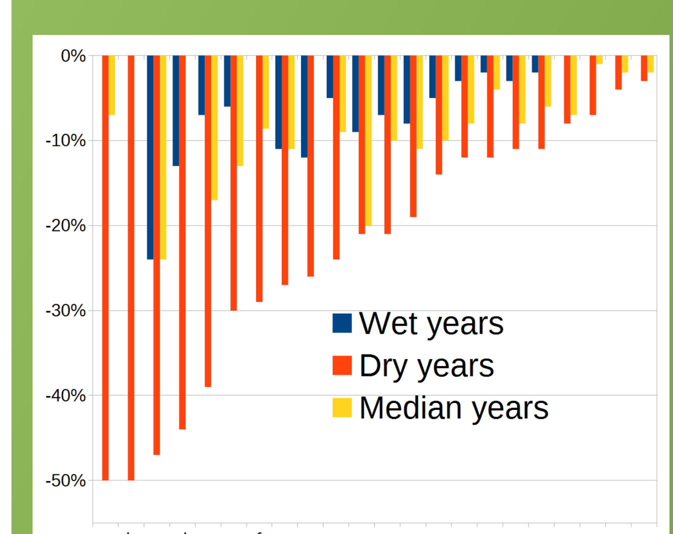


Figure 3 :Stream discharge decrease for wet, median and dry years. Every bar corresponds to a catchment for which the stream discharge decrease was estimated.

- Cumulative impact is mainly estimated in considering annual stream discharge
- Annual stream discharge descrease 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 betweem 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 variouscatchments 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 persuqare kilometre and as volume stored per suqare kilometre, annual precipitation, or specific discharge. Every point represents a catchment.

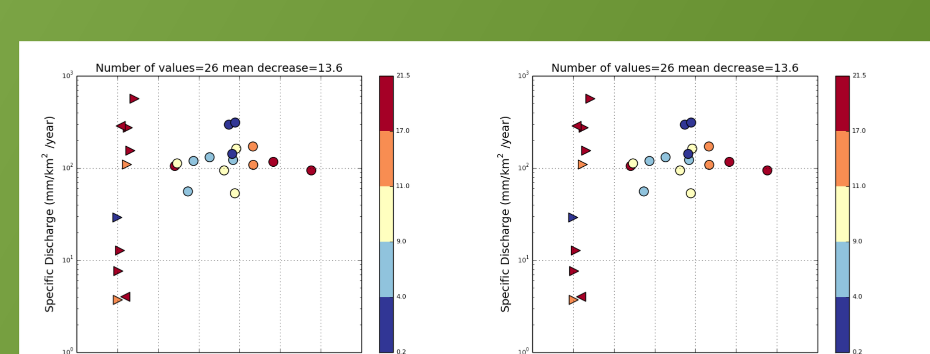


Figure 6 : Small reservoirs in a) France, b) Tunisia, c) Australia and d) India.

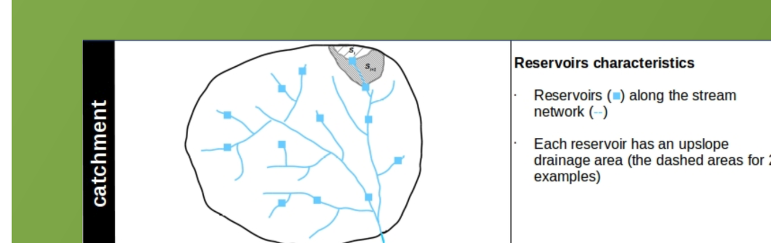
Two main approaches for estimation

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



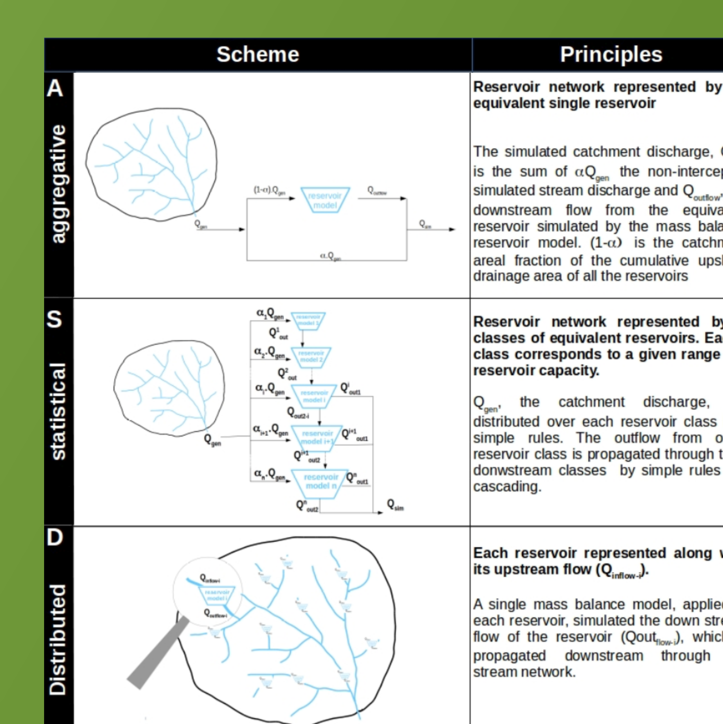


Figure 5 :Catchment and reservoir network to model (above). Spatial representation of reservoir network in models used to quantify cumulative hydrological impacts. (Right)

- 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

Esimations of cumulative impact of small reservoirs are very sensitive to estimation of absractions 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.ASSESMENT.REPORT.05.2016

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