Response to comments – Referee #1

This manuscript describes the cumulative impact of small reservoirs on the hydrology of a small catchment area in south-western France. These reservoirs are generated randomly and are connected to the river network. Their characteristics include their water storage capacity, their spatial distribution across the catchment area and their number. The metrics used to assess the impact of these different components are annual flows, summer flows, and the proportion of the hydrographic network at low flow each year. The study is based on 20-year numerical simulations. It shows that the impact of reservoirs is cumulative along the river network and assesses the effects of the distribution, number and capacity of reservoirs on flows, and studies the associated processes. This work is very interesting and also sensitive because it attempts to provide answers to societal questions, in particular the storage of water for irrigation in dedicated reservoirs.

I find this article very well structured and well written. The conclusions are based on objective evidence and clear figures, and the limitations of the study are well presented in the discussion. I recommend publication of this article after minor revisions.

Comments:

- L109: evaporation from the reservoir is considered to be 60% of the reference evaporation, which I assume corresponds to potential evapotranspiration. How valid is this approximation and what is the associated uncertainty? It is important to give an order of magnitude for annual evaporation, as well as annual withdrawals, as these contribute to direct mass loss.

The relationship between reference evapotranspiration (in our case calculated with the Penman-Monteith equation) and actual pond evaporation in MHYDAS-small-reservoir is purely empirical. We adopted a coefficient of 0.6, which is the value most commonly applied in SWAT model applications for simulating actual pond evaporation (Neitsch et al., 2011).

Such empirical relationships are widely used in models representing small reservoirs. However, few studies explicitly report the coefficient value used. Among the 30+ approaches we identified for modeling small farm reservoirs in hydrological models, only 4 give the used value for this parameter (though not all of these approaches model evaporation or use the same method). Jayatilaka et al. (2003) use a value of 0.8 in the model CASCADE, Peter et al. (2014) a value of 0.7 in ResNetM, McMurray (2006) a value of 0.75 (in winter only), and Rabelo (2021) a value of 1.0 in a modified version of SWAT. Note that the three first use the A-pan evapotranspiration as reference.

The reported values vary across studies, which is expected since the climatic context varies between studies. Only, there is limited empirical evidence to guide the selection of an appropriate coefficient. In Southwestern France, no studies are available to justify the choice of one value over another. In a Mediterranean context, where evaporative demand is higher, Martinez-Alvarez et al. (2007) used a modeling approach (energy balance) to derive relationships between A-pan evapotranspiration (measured) and evaporation from irrigation reservoirs (modeled). They found that the pan-coefficient, as they term it, varies throughout the year, with the local weather conditions, and the dimensions of reservoirs. Values are ranging from 0.5-0.6 to 1.2, and are mostly comprised between 0.8 and 1.1. Since the A-pan evaporation is typically higher than the Penman-Monteith evapotranspiration (Allen et al., 1998, Chapter 4), coefficients between Penman-Monteith evapotranspiration and actual evaporation close to or higher than 1 would be justified in this context.

Selecting an appropriate proportionality coefficient is not straightforward. In the case of our numerical experiment, we can assume that the exact value will not have much impacts on the results. Given that the reference evapotranspiration and the actual evaporation are assumed to be proportional, a 50% increase of the coefficient of proportionality would likely result in a 50% increase in actual evaporation (probably a bit less since the surface of the reservoir also decreases). In our experiment, withdrawals are much more important than evaporation, particularly in summer (see supplementary material Figure S6). **Thus, a 50-60% increase in evaporation would have little impact on the outcomes of the numerical experiment. Nonetheless, we acknowledge that our initial choice of 0.6 requires reevaluation in the future, for any context in which the model will be applied.** Reviewer 3 drew our attention to McMahon et al. (2013), which will be a good starting point for this.

To clarify this point for readers, we propose adding the following sentence at line 194 : "With these values for reservoir capacity and irrigable crop surface, reservoirs will be intensively managed. As a result, withdrawals will significantly exceed evaporation losses, which will not be further analyzed in this study (see supplementary material Figure S6 for a comparison of withdrawals and evaporation)."

- L117: withdrawals are possible if the volume of water is greater than 1/4 of the reservoir's capacity: what average water depth does this correspond to, given that the shape is an inverted pyramid? Is this compatible with the characteristics of the withdrawal pumps?

Withdrawals are not permitted when the water volume falls below a minimum threshold. This aims to preserve the pumping equipment and the quality of irrigated water. The threshold was fixed to ¼ of capacity arbitrarily, without considering a specific depth or pump characteristics. This "dead volume" has minimal impact on our results, as tested reservoir capacities were scaled considering that only ¾ of it would be usable.

Given that this point was unclear to the other reviewers, we propose to add the following clarification in L117 : "However, withdrawals from a reservoir are only possible if the water volume exceeds a predefined threshold to preserve the pumping equipment and ensure the quality of irrigated water. In MHYDAS-small-reservoir, the threshold was set at 1/4 of the reservoir's capacity. Since this "dead volume" was accounted for in the design of the numerical experiment, (see 2.2.3), its exact value is expected to have a limited effects on the study's results".

- L114: on the map of France in Figure 1, there are white pixels in the Rhone valley that should not be there. What do they correspond to?

Thank you for this pointing this out. This is an oversight on our part. It will be corrected in the revised manuscript.

- L127: average annual rainfall is 675 mm: how was this calculated? Using SAFRAN data or measurements from rain gauges located in the catchment area?

This was calculated using SAFRAN data. As part of our field instrumentation on the Gélon catchment, we have a single rain gauge located at the outlet of the catchment. The available record is currently limited to less than 10 years. For the years with available data, there is a good agreement between the measured data and the SAFRAN data.

- L128: The total volume capacity of the reservoirs in the basin is estimated at 205,000 m^3. Is this estimate based on the pyramidal shape of the reservoirs or does it come from data describing the various structures?

The data on small reservoirs were obtained from a previous work in a larger area conducted by another laboratory. This study combined multiple databases from various organizations to collect as much information as possible on small reservoirs in the area. Therefore, the data were collected using different methodologies, including field surveys and satellite imagery. For the Gélon catchment, we performed a validation on the field for the 25 reservoirs. As some values of reservoir capacity were obviously incorrect in the database, these were coarsely estimated on the field and corrected.

- L140: What do you mean by “better match expectations”?

In the model used by Lebon et al. (2022), groundwater units were drained only at confluences between two portions of the hydrological network, meaning that the stream discharge between a stream network head and the downstream confluence consisted solely of surface runoff water. In our context of numerous hill aquifers, however, aquifers are drained all along the hydrological network, not only at confluences. The new groundwater units now better capture this continuous groundwater discharge. That is what we meant with “better match expectations”.

To clarify this point, we propose to change “but the discharges in the hydrological network better matched expectations” to : “but the new groundwater units better represent a continuous water supply from subsurface hill aquifers along the hydrological network”.

- L147: An example of one or two reservoir distributions would be helpful. For example, showing one distribution of the 7, 14 or 21 downstream reservoirs with the two capacities (two colours) as in Figure 1 and the main irrigable crop would help to clarify the ideas.

Examples of reservoir distributions can already be found in the supplementary material (Figures S2 and S3).

Considering this commentary and similar feedback from the other reviewer, we propose moving figure S2 from the supplementary materials to the main article. An improved version of the figure is presented below.

The reference to the supplementary material will be made more explicit so that readers can more easily find figure S3, which provides three examples of networks generated with each of the three methods.

- L180: what is the proportion of reservoirs not connected to the hydrographic network compared to those that are connected? They also contribute to water storage for irrigation.

In the Gélon catchment, 9 reservoirs are not connected to the hydrological network. They have been removed in the numerical experiment as explained in 2.2.4. The addition of the new figure proposed above will also clarify this point.

- L225: a warm-up period of 5 years is considered: does this mean that the simulated data used start in September 2000? Or is the warm-up from 1990 to 1995? Please clarify.

25 years are simulated, and among these 25 years, only 20 can be analyzed. The analysis can start on 2000/09/01. Note that in the result section, only 19 years are analyzed, starting on 2001/04/01 as

it was more relevant to study the impact of reservoirs on a period where they are first emptied and then refilled.

We propose to change “These five years are not included in the analysis” to : “These five years are not included in the analysis. Therefore, the analysis can start in September 2000.”

- L233: references to Vidal et al. (2010) and Le Moigne et al. (2020) can be added for SAFRAN. Can you clarify if the reference evapotranspiration is computed from SAFRAN data and at what frequency? Same question for min and max temperatures, do they come from the SAFRAN reanalysis?

For Vidal et al. (2010), we found a reference with the following doi : 10.1002/joc.2003. This does indeed appear to be an important reference, which we will add into the paper (see below our proposed reformulation).

For Le Moigne et al. (2020), we found a reference with the following doi : https://doi.org/10.5194/gmd-13-3925-2020. Although the authors use SAFRAN as a component of their hydrometeorological model, we determined that it does not provide additional relevant information regarding the SAFRAN dataset for our study. Therefore, we have decided not to include this reference.

Thank you for asking about the exact meteorological data used in our study. We realized that we made an error in this regard in the preprint. The data was obtained in mid-summer 2024 with the latest reanalysis. Below are the exact products that we used for each input variable :

Rainfall : hourly values (column Rainf).

T_moy : hourly values (column Tair).

T_min : daily values (column tinf_h_q).

ET0 : daily values (column etp_q, which corresponds to potential evaporation computed with the Penman-Monteith equation).

We propose a new formulation for this paragraph (see our answer to your commentary below).

- L236: You state that meteorological data variability is taken into account: I would temper this statement, as the climate in such a small area, covered by four contiguous points, probably does not vary greatly, at least you have not demonstrated that it does. I suggest removing this idea of variability. However, it is interesting to note that Gélon covers only four cells of the SAFRAN grid. Further on, you only take one cell (8558) into account in your comparison. You could at least show that the annual precipitation for these four grid points is very similar, which would allow you to take only one into account.

Thank you to draw our attention on this point. The statement will be removed. First, we made another mistake, the Gélon only intersects two cells (this will be rectified). Second, more than 97% of the catchment is located on the same cell, that’s why we only presented this cell (see Figure 43 in Lebon 2021).

We propose to change this paragraph to : “The weather data are composed of hourly SAFRAN data for rainfall and temperature, and daily data for the minimum daily temperature and reference evapotranspiration (Penman-Monteith). The SAFRAN climatic data are provided by Météo-France and were downloaded via the SICLIMA platform developed by AgroClim-INRAE. The data are reanalysis of observed data on 8x8 km2 cells (Bertuzzi et al., 2022; Vidal et al., 2010). The Gélon catchment intersects with 2 of these cells. One of these two covers more than 97 % of the catchment area. The seasonal rainfall for the main cell is presented in Figure 2."

- L252: Figure 2, Medians are extending before 2001 and after 2019: do they use data covering 2000-2020? If not lines must be croped to adjust to 2001-2019.

Medians were computed for the presented period, which will be the period of analysis for the other Figures. This will be modified.

- L300: the sentence 'highlights the role of weather' is not very adapted and accurate: please rephrase

True, we propose to change it for : "which shows that the weather is a determinant factor of reservoir impacts".

- L321: (i) and (v) are the same, (v) is the autumn proportion of the framework in low flow

OK, thanks !

- L327: Fig 5 (a) and (d) respectively

OK, thanks !

- L329: 'the boxes are more separated' is not very adapted, perhaps change it into 'each year, the departure to the median is systematically more pronounced in (a) as compared to (d)'

We propose to change it for: "each year, the intersection between boxes is systematically smaller in (a) as compared to (d)."

- L403: equation should be y=-(3/4)x ; in Figure 7 equations should contain brakets y=-(a/b)x

OK, this will be changed.

Edits:

- L222: parameterization OK, thanks !

- L166: reservoir OK, thanks !

- L176: 1.06 km^{-2} OK, thanks !

- L250: reference simulation

In the paper, we frequently use the reference situation to refer to the scenario without reservoirs, or to refer to the simulation of this reference situation. As we never use the term "reference simulation", we think it would be clearer to keep "reference situation" in L250.

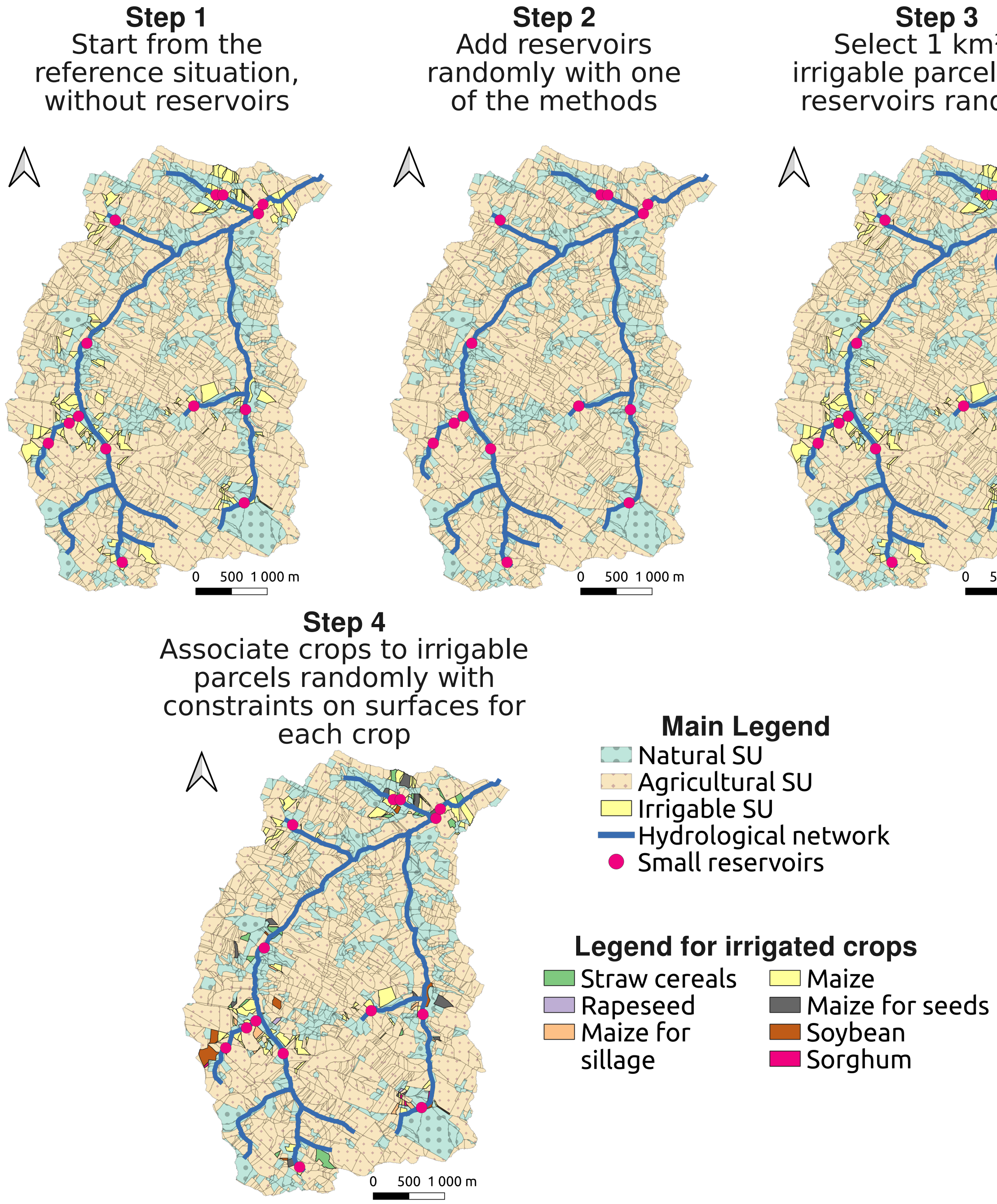

Figure 1: The four processing steps to generate a network of reservoir with associated irrigable parcels. The generated network correspond to one of the five networks generated with the following parameters : total capacity: 140000 m³; number of reservoirs: 14; Method for reservoir distribution: balanced. This figure will be moved from the supplementary materials (currently Figure S2) to the main text (in pdf quality). Colors have been changed to be more adapted for colorblind persons.

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