Response to comments – Referee #3

This manuscript examines the impact of small dams on the flow regime in a small catchment in south western France. The aim of the study appears to be to systematically assess how the spatial arrangements and physical characteristics of dams affect their hydrological impact.

The study uses a series of randomly generated arrangements of dams placed on the stream network with randomly generated physical characteristics. While many studies tend to focus on annual flows, this study assesses additional flow metrics including seasonal flows and the proportion of the stream network experiencing low flows. Notably, it models the effect of irrigation return flows which is novel. This appears to have a significant effect on results.

The results highlight some interesting relationships between the hydrological impacts and the number, volume, and arrangement of dams. However, there are a small number of assumptions which limit the applicability, including the use of water for irrigation with return flows, passing environmental flows, and limiting withdrawals to the top 75% of dam capacity. Modifying these parameters (perhaps in future studies) could provide results which are relevant to many other contexts and jurisdictions.

The article is well written, easy to understand, and clearly structured. The discussion and results are relevant for the fields of water resources management and hydrology. I am keen to see this paper published, however as noted by other reviewers, it could be improved with some minor revisions.

Specific comments:

L109 – Evaporation from the surface of each dam is assumed to be equal to 60% of ET. This may be appropriate, but it would be good to see some justification for this. Other evaporation variables may be more suitable for this purpose, such as Morton's shallow lake evaporation (refer to doi 10.5194/hess-17-1331-2013).

We used the value of 0.6, which is the one most commonly applied in SWAT model applications for simulating actual pond evaporation. Our approach to modeling pond evaporation is empirical, and while it is widely used in hydrological models to represent small reservoir evaporation, few studies report the coefficient values used. We acknowledge that the representation of evaporation could be improved in our model, and we thank you for providing the useful reference.

In our experiment, withdrawals is the main loss term on reservoirs (see Supplementary Figure S6). Consequently, a change in reservoir evaporation would probably have only a limited impact on our results. This justifies our decision not to focus further on refining our approach to pond evaporation yet.

We propose adding the following sentence at line 194 (same proposal as for Reviewer #1 who raised a similar question) : "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)."

L114 – In the results section, many references are made to return flows from irrigation. This feature of the model and assumptions around it are not described anywhere in the method (eg. percent of flow returned, which reach does irrigation water return to). I would expect to find this information in Section 2.1.3. I realise this information may be present in one of the references given, but it appears to be important for this study so it needs to be provided here.

This point was also raised by Reviewer #2. In our paper, we incorrectly assumed that the concept of irrigation return flows was widely understood. This term refers to the portion of irrigated water that is neither evaporated nor transpired, but instead percolates to groundwater and consequently may further re-enters the hydrological network. Our model does not assume a fixed proportion of irrigation return flows for a given irrigation height. These are computed as part of the percolation from the soil water balance in the soil-crop model. *A posteriori*, we observe that streamflow increases in late summer and autumn in situations with irrigation compared to the non-irrigated reference situation. We attribute this increase to irrigation return flows. By comparing the change in outlet discharge and the total withdrawals in reservoirs, we can estimate these return flow. If all withdrawn water for irrigation was evaporated or transpired, the net decrease in outlet discharge would equal the total withdrawals. Figure 7 of the paper shows that the net decrease ranges between ½ and 1 times the withdrawals,with the difference representing irrigation return flows.

For more consistency in the result section, we propose (same proposal as for Reviewer #2) :

- Removing the introduction of irrigation return flow in L298. This paragraph (3.1.2) aims at describing the observed impacts. The statement on irrigation return flow is an interpretation and does not belong here.
- Defining the irrigation return flows in the dedicated section (3.3.1 Withdrawals volumes and irrigation return flows), in L405 : "Thus, on average, 3/4 of the irrigation water is used by the plants or evaporated. The remaining ¼ returned to the hydrological network as irrigation return flow, defined as the portion of irrigation water that flows back to the hydrological network (Poch-Masségú et al., 2014). Irrigation increases soil water content. The applied water can therefore contribute to different fluxes, i.e. (i) crop transpiration, (ii) soil evaporation, and (iii) percolation. Irrigation return flows occur when part of the irrigated water percolates to groundwater, which increases water table levels and streamflows. Since percolation only occurs when soils water content is above field capicity, irrigation return flows can be delayed compared to the irrigation period. The timing and amount of irrigation return flow can be critical for understanding the effects of small reservoirs, not only on outlet discharges, but also on low flows. These return flows can explain why, for some years, the autumnal outlet discharge increases compared to the reference situation (e.g. 2002, 2005, 2006, 2011, 2017). These return flows occur at reach sections that are located near irrigated fields, and can locally sustain flows during dry period. That explains why the proportion of network in low-flow decreases for some years, especially in autumn (e.g. 2001, 2016, 2017). To explain the variability observed ..."

L117 – As others have noted, assuming no withdrawals if the dams is below 25% capacity seems arbitrary. Is this a regulated limit? Or standard operating procedure? In most parts of the world, farmers will extract water from their dams until it is just a small pool of mud. A 10 word explanation is fine.

As your comment is related to a comment of Reviewer #1, we will provide the same response.

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.

As suggested, we propose adding 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”.

L155 – I do not quite understand the scenarios. In particular, the phrase ‘each combination of modalities is repeated 5 times’ is not clear. Exactly what is repeated 5 times? And what is different about each of these 5 scenarios?

The key point of our numerical experiment is the random generation of reservoir networks. Our network generator requires three parameters : the number of reservoirs, the total capacity to be distributed between these reservoirs, and a parameter controlling the random spatial distribution of reservoirs (upstream vs downstream). The experimental plan consists in testing three different values for the number of reservoirs, two for the total capacity, and three for the distribution of reservoirs. Since network generation is stochastic, we performed five repetitions for each combination of parameters, resulting in a total of 90 generated networks and 90 simulations (3 × 2 × 3 × 5).

As the network generation process was unclear to another other reviewer also, we propose moving figure S2 from the supplementary material to the main article. An improved version of the figure is presented at this end of this document.

Table 2 – Typically, I would expect dams to have effects throughout summer and into autumn while they are filling. This extends the summer low flow season further into autumn. Some results here seem to show slightly different autumn results where irrigation return flows are significant. An interesting follow up study could be to repeat the study with water withdrawals for stock or domestic use with no irrigation returns, or without the 10% environmental flow requirement which is not required in many other jurisdictions. The results may appear quite different. I recommend the paper briefly recognises that these results are dependant on some assumptions which may not always be applicable in other locations.

You’re right. As is the case for any study on small farm reservoirs, our results are context dependent. Throughout the paper, we tried to clearly present our context and assumptions. At the beginning of the discussion (L429 to L444), we give the domain of validity of the results, the “specific context of irrigated field crop in catchments dominated by shallow groundwater and clay loam soils”.

As Table 2 summarizes our result, we propose adding in the caption a statement to reaffirm that these results are context dependent : “Table 2. Summary table of the effect of the three study factors on five indicators of impacts **found in the numerical experiment**. **These results are valid in the context of the study.** The first line indicates the global effect (and). The other lines indicate the effect and the mean order of importance of each factor in the ANOVA (indicated by the number in brackets). Empty cases indicates that the factor has no impact on the indicator. Low flow refers to the indicator of the proportion of the network in low flow. An increase in low flow is perceived as a negative impact. For the autumnal low flow, only years with more than 20 % of low flow in the reference situation were retained to address the variability in the ANOVA. ”

As explained above, we cannot turn on or turn off the irrigation return flows. Their importance may vary in other contexts (e.g. deeper soils, different hydrological functioning, more conservative irrigation).
Please note that this article is part of the PhD work of Henri Lechevallier. The question of reservoir management and especially the connection to the stream appears central to us also. Therefore, it will be the focus of a second numerical experiment, which we intend to publish in the future.

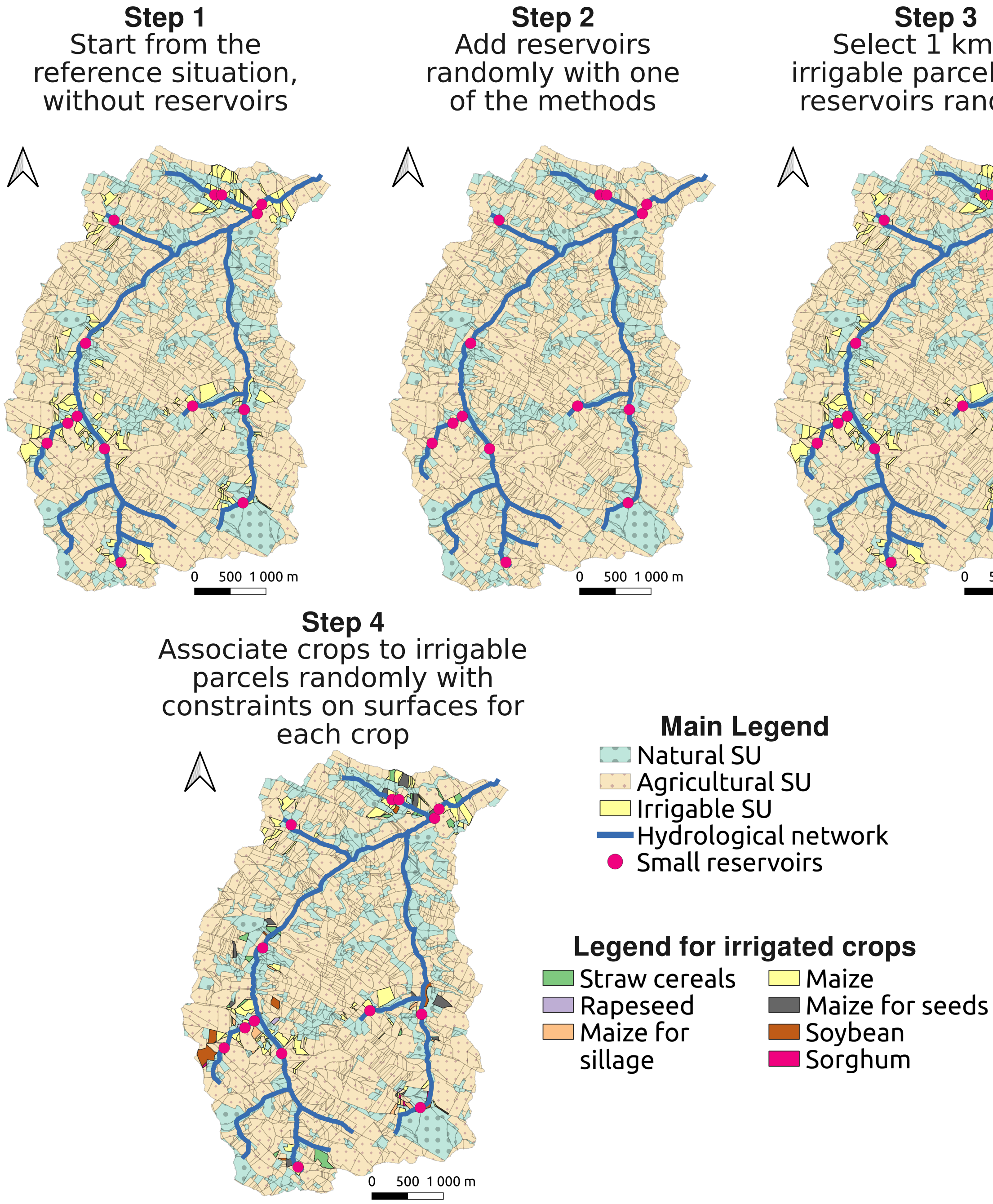

Figure 1: The four processing steps to generate a network of reservoir with associated irrigable parcels. The generated network correspond to one of the five networks generated with the following parameters : total capacity: 140000 m³; number of reservoirs: 14; Method for reservoir distribution: balanced. 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.