Response to comments – Referee #2

The article presents an analysis on impacts of the variability of small reservoirs networks configuration in terms of their number, storage capacity and distribution in space. As the authors state, this type of investigation is a new addition to the study of small reservoirs impacts on the water cycle. The article is well written, and the authors described with clarity and detail the configuration tested and the outcomes they achieved. Below I've listed some comments to the authors, mainly clarification of some parts, then some edits to the text.

I suggest the article to be published after minor revision addressing the comments below.

Comments/revisions

Line 94: only agricultural and natural surfaces are referenced, is the model not able to represent urban surfaces, or was this a deliberate choice? This could be addressed in the text

Currently, the model cannot represent urban surfaces. Since the urban areas only represent 4.5 % of the total surface (about 0.9 km²), they were assimilated to natural surfaces for model calibration and validation in Lebon et al. (2022).

We propose to add a sentence in L99 : "Urban areas are assimilated to natural surfaces in the model, as they usually cover a small fraction of agricultural catchments".

Line 109-110: I think a small justification for not considering percolation from the bed and walls could be provided here. The authors for example state in another part that the soil is mostly impermeable, this could be an explanation but it is not explicit

Small reservoirs are build to store water for irrigation and to limit water losses by percolation. We assume that this is achieved by using local material to construct the dam walls ensure the reservoir's impermeability. In the reality, such reservoirs can leak. Since we do not have any estimation of this term in our context, we assume that leakage is negligible.

We propose to add a brief justification in the paper L109 : "Percolation from the reservoir bed to groundwater or through the dam wall is not considered in the model, as leakage is assumed to be negligible in this context of fine textured soils."

Line 117: is this decision backed by some prior knowledge e.g. based on small reservoirs functionality?

Below a given level in the reservoir, pumping becomes more difficult as sediments can damage pumps. The 25 % threshold is arbitrary, and has only a limited effect in the numerical experiment, as the total capacity has been fixed accounting for this "dead volume" (see our answer to Referee #1 on the topic). *A posteriori* and given the limited impact of these restrictions, it would certainly have been clearer to not consider any restrictions, and test the values of 210000 m³ and 105000 m³ for the total capacity in the numerical experiment.

We propose changing the sentence L117 to clarify this point : "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 effect on the study’s results”.

Line 179-180: the authors could provide more details explaining what are the "specific locations" of the reservoirs

Here, “specific locations” means that hill reservoirs are usually found in locations that are not fully random, but that could be considered as “strategic” in terms of drained area and the surface runoff generated within it. Field observations also indicates that these reservoirs are often positioned to intercept subsurface flow.

We propose adding the following clarification in the sentence : “As hill reservoirs are usually found in locations where surface and subsurface flow converge, which is not captured by the model, a random placement would not be meaningful for this type of reservoir”.

Line 180: at Line 96, the hydrological network is defined as the RSs. In Figure 1, REs are not all located on RSs. This is in conflict with the sentence at line 180-1.

Figure 1 shows the current distribution of reservoirs in the Gélon catchment, with both hill reservoirs and small dams. In the numerical experiment, we remove all reservoirs before generating a new reservoir network, with connected reservoirs only. See the Supplementary material Figure S2 and S3 for examples of generated reservoir networks.

To improve the clarity of the presentation of the numerical experiment, we propose moving figure S2 from the supplementary material to the main text. An improved version of the figure is presented at this end of this document.

Line 221: the authors could state here at what time steps the simulations are performed

In line 92, we precise that the model runs at an hourly time step for water routing and a daily time step for crop growth. According to us, it is not necessary to repeat it in line 221.

Line 298: the authors introduce here "irrigation return flows", which are later addressed in a dedicated section, but it is not clear to me what these flows are or why they happen, are they a component of the model? How and why does it return to the hydrological network? The reservoirs are emptied at the end of the irrigation season? Is this happening in reality?

Irrigation water entering the soil increases soil water content. Soil water can either (i) be transpired by plants, (ii) evaporate to the atmosphere, (iii) percolate to groundwater. At harvest, not all irrigation water has necessarily been used by plants or evaporated. Some of it either leached to groundwater, or still remains in the soil, and will eventually percolate later once the soil reaches saturation after subsequent rain events. These percolation fluxes that would not happen without irrigation increase groundwater stocks and therefore streamflows. Such additional flows, generated by irrigation, are referred to as irrigation return flows. They represent water losses from an agricultural standpoint, and are often studied in the context of nutrient and pesticides leaching (Causapé et al., 2006; Poch-Massegú et al., 2014).

For more consistency in the result section, we propose :

- 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-Massegú 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 ..."

Line 391-392: withdrawals are based on the decision model. Can observation (i) be proposed as an "absolute" observation as it is proposed here?

Figure 7 shows that the decrease in outlet discharge is linked with the amount of withdrawals. This result is expected. On the Figure, we see that withdrawals are higher in situations with higher storage capacities (with equal irrigable surface), which was also expected since the lowest value of capacity was design to be insufficient to cover all water demand. In a real case, we can expect that farmers with larger reservoirs will also tend to irrigate more by expanding irrigated areas or increasing irrigation rates, provided that reservoirs can be fully recharged during the wet season. Our list of observations starting in L391 only describes and helps interpret Figure 7 and are specific to our context. At the beginning of the discussion (L429), we stress that our results are to be interpreted considering the study context, i.e. the context of "irrigated field crop in catchments dominated by shallow groundwater and clay loam soils", which also includes the assumptions regarding farmer water use embedded in the decision model. We opened the discussion with these statements to stress that the impacts of small reservoirs inherently depend on their management and usage, which should be explicitly addressed in this type of work. In our case, we specify the management rules in paragraphs 2.1.2 and 2.1.3 (i.e intense use of water when available). Additionally, paragraph 2.2.3 specifies that reservoir capacities were chosen based on the mean yearly irrigation water demand, meaning that the stored volume will not always be sufficient to cover all needs, especially in situations with 140000 m^3 of storage capacity.

Edits

Line 13: here, "low flow proportions" is not too clear, I would change to "the proportion of low flow"

Ok, it will be done in the revised version.

Line 14: would change to "For the two indicators", since they are presented a few sentences before

Ok, it will be done in the revised version.

Line 43-44: reference to Colombo et al., 2024 can be done as a more recent example of small reservoirs cumulative impacts study through modeling (https://doi.org/10.1016/j.jhydrol.2024.130640)

Ok, it will be done in the revised version.

Line 78: streamflow

Ok, it will be done in the revised version.

Line 276: i would suggest to put (no reservoirs) after "reference situation"

Ok, it will be done in the revised version.

Line 418: I would remove "figure not shown"

Ok, it will be done in the revised version.

Table 2 caption: where the upward and downward arrows are indicated I would add text stating something like "increase" and "decrease", as it could be misunderstood as "positive" and "negative"

Ok, it will be done in the revised version.

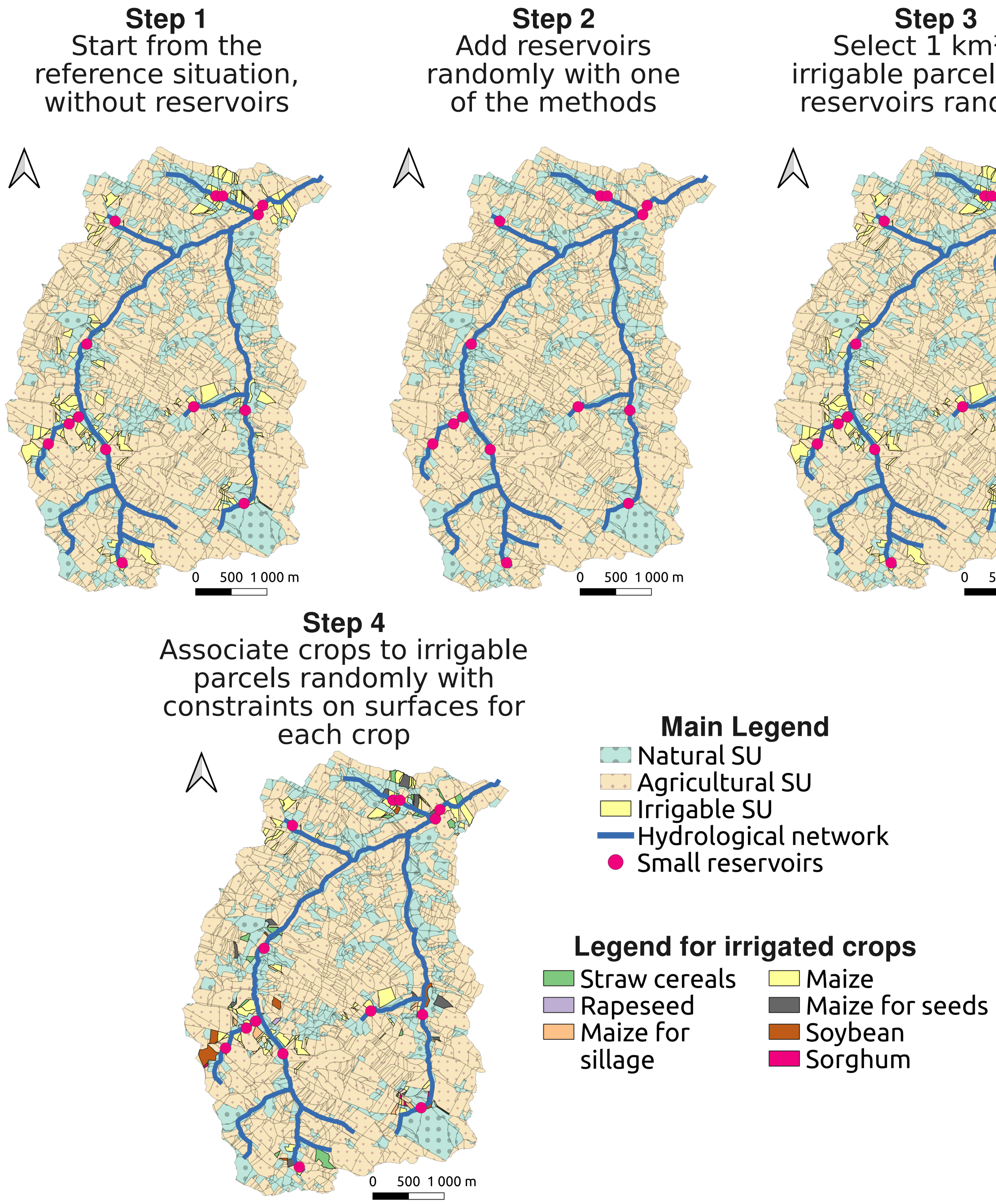

Figure 1: The four processing steps to generate a network of reservoir with associated irrigable parcels. The generated network correspond to one of the five networks generated with the following parameters : total capacity: 140000 m³; number of reservoirs: 14; Method for reservoir distribution: balanced.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

References

Causapé, J., Quílez, D., & Aragüés, R. (2006). Irrigation Efficiency and Quality of Irrigation Return Flows in the Ebro River Basin : An Overview. *Environmental Monitoring and Assessment*, *117*(1), 451-461. https://doi.org/10.1007/s10661-006-0763-8

Lebon, N., Dagès, C., Burger-Leenhardt, D., & Molénat, J. (2022). A new agro-hydrological catchment model to assess the cumulative impact of small reservoirs. *Environmental Modelling & Software*, *153*, 105409. https://doi.org/10.1016/j.envsoft.2022.105409

Poch-Massegú, R., Jiménez-Martínez, J., Wallis, K. J., Ramírez de Cartagena, F., & Candela, L. (2014). Irrigation return flow and nitrate leaching under different crops and irrigation methods in Western Mediterranean weather conditions. *Agricultural Water Management*, *134*, 1-13. https://doi.org/10.1016/j.agwat.2013.11.017