

Interactive comment on “Small farm dams: impact on river flows and sustainability in a context of climate change” by F. Habets et al.

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This paper discusses the hydrological impacts of small farm dams on river flows in France as a function of spatial variations in hydrometeorological conditions, primarily precipitation patterns. The hydrological impacts were explored utilizing a small farm dam model connected to a hydrometeorological model, with several scenarios related to different filling capacities, catchment size and filling period being utilized. Although the perceived need for such dams in western France is high, the model results suggest that the creation of such dams, particularly in NW France, would result in significant impacts on river flows as well as relatively inefficient filling of the ponds, particularly in the context of climate

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change. The ability of the dams to increase irrigation water availability is limited by the decreased ability of the tanks to fill up under climate change. In general, it is shown that areas where the impact of small farm dams on streamflow is the greatest, the filling efficiency of the dams is also the lowest. General Comments The authors make an important point that the use of small surface-water retention ponds such as the farm dams of southwestern France will impact the water balance of a basin. While increasing the availability of irrigation water, the dams can decrease river flows or provide very inefficient filling. It is also correctly noted that while the need for increased irrigation water is most acute during drought years, and may increase further in the face of climate change scenarios, such structures are least able to provide adequate levels of supplemental irrigation during drought years. The overall contribution of such structures may therefore be overestimated.

We would like to thank the reviewer for his/her careful analysis of our works. We realize that such clear summary was not provided in the article, and we have modified the conclusion to include it: *" In these regions, the dams are less able to fill up, and thus to supply water to the farmers, and the presence of the dams lead to a decrease of the flow larger than in other regions. The impact of such dams is exacerbated during dry years, even though they are barely filled up at more than 50% in these regions."*

The paper, however, has a number of points that should be addressed: 1) Although the above points are made, they could be made more clearly. For example, the authors often note "impacts" on streamflow, but don't clarify what these impacts are, or the implications of the impacts."

It is completely true that the word "impact" is often used whereas a more specific term could be used. Some corrections are made, especially in order to explain which are the expected impact of the small farm dams. Modifications are listed below:

- abstract: *"Although such dams are small, their accumulation in a basin affects*

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the river flows, since the water collected in those small farm dams is used for irrigation and thus does not contribute to river flow. In order to gain more insight into their impact on the annual and monthly discharges, with a special focus in dry years, a small farm dam model was built and connected to a hydrometeorological model. Several scenarios with different volume capacity, filling catchment size and filling period were tested for such dams"

- abstract: the word decreases is used instead of impacts, and some more details are given in *"It was found that, due to the hydrometeorological conditions (mainly precipitation), the development of small farm dams in north-western France would lead to larger decreases on the riverflows and to less efficient filling of the small farm dams than in other regions of France, so that in these regions, such dams might not be as efficient as expected to supply water to the farmers when they need it.."*
- introduction: a new sentence is added: *"Indeed, it is expected that water withdrawals or derivations to fill the small farm dams lead to a reduction of the discharge during the filling period (that is restricted to the high flow period), allowing the use of the stored water for irrigation in summer without affecting the discharge during low flow."*
- introduction: *"a reduction of the winter flood"* is used instead of *"impacted the winter flood"*
- introduction: *"the small farm dams induced a decrease of the annual discharge that could reach 10%"*
- introduction: *"and found that the decrease of the riverflows is limited to the downstream basin."*
- introduction: the main questions are now more detailed: *" What is the maximum water volume that can be stored in the irrigation dams without having too great an*

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impact on the annual and monthly discharges ? Especially, what are the impacts on the floods occurring in autumn, that are important for the migration of fish and for their morphogenic contributions ? Are those dams really able to provide water to the farmers during the dryer years, and what are then their impact on the dry year river flows? "

- introduction: *"The impacts of the small farm dams on the river flows of the Layon basin are detailed below, as well as the ability of these dams to fill up in various climate conditions"*
- section 2.2 "The small farm dam model": the sentence was clarified: *" Focusing on the riverflow at the outlet, it was found that it is rather similar to take into account few larger dams aggregated on an 8-km grid as to simulate several small dams as long as they are sparsely distributed in the basin (i.e. not all located on the same tributary)."*
- section 2.3 "Assessment method": The variables of interest are more detailed in the new section "Assessment method". *"The variables of interest are the filling efficiency and the impacts on the riverflows. The filling efficiency of the dams is estimated based on their maximum filling stages simulated each year according to the climatic conditions (including the dry years) compared to their maximum volume capacity, The expected decrease of the river flows associated to the presence of the small farm dams is quantified on monthly and annual time scales, with a special attention on the low and high flows for the local scale, and on the dry years. Indeed, in case of drought, water use may be restricted by law, to the point of requisition water stored in dams to sustain river flow. However, the large number of small dams makes it difficult to apply this law to small farm dams, which reinforces the interest to quantify their impact on flows during dry years."*
- section 3 "simulation of the Layon basin": *" Then, the inclusion of the small farm dams in the model allows to account for the reduction of the river flow linked to the*

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storage of the runoff in the dams that is considered as a lost for the hydrosystem since the water is then used for irrigation. The simulated river flows are then expected to be closer to the observations, and the comparison between the two simulations allows quantifying the impact of the dams on the discharge"

- section 3.2.2 "Impact on river flow": *" Thus Fig 5. shows, quite logically, that the reduction of the discharge due to the presence of the dams is greater in the first month of the filling period..."*
- section 3.2.2 "Impact on river flow": *" The frequency distribution of the decrease of the annual discharge associated to the presence of the small farm dams is presented in Figure 6".*
- section 3.2.3 "Focus on a dry year": *"The decrease of the annual discharge is considerable, -40% and -30%, respectively, for the two-dam implementations discussed above."*
- section 4 "Results over France": *"More surprising, the mean decrease of the annual discharge is also lower than 2% in south-western France even though the dams there have a high mean annual filling ratio."*
- section 4 "Results over France": *" In contrast, the decrease of the mean annual discharge are larger than 5% in most parts of the Seine basin,..."*
- section 5 "Projection in a context of climate change": *"Fig. 16 shows the impact of small farm dams in the annual discharge in 2050 compared to the simulation in 2050 without small farm dams"*
- section 5.1 "Combined impacts of small farm dams and climate change on the Layon basin": *"Although the climate projections show considerable dispersion, the impact of climate change and small farm dams in the first month of the filling period is large, with a decrease of the discharge ranging from -40% to -80%."*

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- section 6 "Discussion": *" By using a simple model of small farm dams and several hypotheses, this study was able to estimate the impact on the river flows of extended small farm dams spread over the Pays de la Loire region..."*
- section 6 "Discussion": it is now specified that the impact is a decrease of the discharge
- section 6 "Discussion": *"The Pays de la Loire region was shown to be one of the regions of France where the decrease of the river discharge due to the presence of the small farm dams is the greatest and where the ability of these dams to supply water to the farmers is the lowest."*

2) For the volume calculations, it is assumed that all irrigation water in the Pays de la Loire region currently comes from small farm dams. A reference should be given to support this assumption.

It was stated section 3 that *"The declared irrigation volume reached 3000000m³ in 1998 SAGE (2002a) and had almost doubled by 2010, the water being mostly stored in small farm dams or being directly pumped from the river or alluvial aquifer SAGE (2002a)."* To be more precise, it is now stated that the irrigation from dams represents about 80% of the irrigated water in the Layon.

It was also stated in section 2 that *"The small farm dam fraction can be estimated using the present day irrigation water volume in the Pays de la Loire region, by considering that all the irrigation water taken from the surface water comes from small farm dams".* It is now added *"as it is the case in the Layon basin (SAGE (2002a))."*

3) It is stated that the impact of dams could reach 10% of the annual discharge - what is this impact? Is it meant that 10% is withheld that would ordinarily go to runoff?

Yes, that is correct, the impact of the small farm dams can reach 10% of the annual discharge in the Pays de la Loire region, and along the river Garonne. It is now clearly

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stated that the presence of the dams leads to a reduction of the annual discharge by 10% (cf answer to the first comment).

4) It is written that "as long as the dams were small and sparsely distributed... the impact was reduced. What impact do you mean? Please clarify.

It is true that this sentence was not clear. This sentence was modified as follow: "*Focusing on the riverflow at the outlet, it was found that it is rather similar to take into account few larger dams aggregated on an 8-km grid as to simulate several small dams as long as they are sparsely distributed in the basin (i.e. not all located on the same tributary).*"

5) The estimated pond area is based on an arbitrary depth value (3 m) and the actual irrigation water used in the region. These estimations, however, do not take into account evaporative losses from the ponds. These evaporative losses should be considered when calculating pond size.

It is correct that farmers should account for evaporation loss to estimate the size of their small farm dams if they need these dams to supply a given volume of water. However, it was not the case in our study, since we have tested different values of the extension of the small farm dams, and thus, of the volume stored in these dams. These areas were expressed as a fraction of the surface of the whole catchment, as it is requested that the total extension of the water body should not exceed 5% of the basin area in the Loire Bretagne basins (SDAGE Loire Bretagne (2009), cf section 2 lines 180-200).

6) In your discussion, you note that evaporative losses would affect the estimated impact on river flow by less than 10%, but it isn't clear why these losses were not included in the model simulations.

It is correct that evaporation losses from the small farm dams were not explicitly accounted for in the modeling. Evaporation losses from the small farm dams can be approximated using a potential evaporation formula for water body, as for instance the

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one proposed by Penman (1948). However, we should then correct the water balance computed by the hydrometeorological model SIM, that is computing the evaporation according to the soil and vegetation types of the full grid cell, with the atmospheric variables of the grid cell. To estimate the full water budget, we should have considered that the water budget from SIM apply on $(100 - D)\%$ of the grid cell, and then to estimate that the evaporation loss from the small farm dams is equal to the PET

$$AET_{gridcell} = (100 - D)/100 AET_{SIM} + D/100 * PET_{waterbody}$$

However, it is expected that the small farm dams are located in the bottom of the valley, in areas that might be quite protected from wind, and thus that the water body evaporation from the small farm dams could be reduced.

In the study we have indeed considered that the AET computed by SIM apply to the whole grid cell, which is similar to expect that the AET is close to the PET of the water body during the filling period. Such hypothesis is certainly more true for a 3-month filling period, since the AET estimated by SIM during this winter season is closer to PET than for the 5-month filling period

As the present study mostly focussed on the impact of the small farm dams on the hydrology, such assumption seems to be reasonable. However, this point was addressed in the discussion, as it is clearly an issue when considering the ability of the small farm dams to supply water for the farmers. To make this point clearer the text in section 2.2 was modified as follow: "*The increased water body evaporation from the small farm dams is neglected, and the evaporation from the dams is considered to be equal to the surrounding environment. The impact of this hypothesis will be discussed in section 6.*"

The discussion was also modified as follow: *In our study, the dam's area was only sensitive via its impact on the storage volume, because the increased evaporation from dams was neglected. More precisely, evaporation from dams was considered to be equal to the evapotranspiration from the surrounded environment. As evaporation*

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from water body is closed to the potential evaporation, the evaporation loss during the filling period was probably underestimated, especially for the 5-month filling period. Moreover, after the filling period, the evaporation losses from the small farm dams reduces the volume store, and thus, the ability of the small farm dams to supply water to the farmers is certainly overestimated in our simulations. Martínez-Granados et al. (2011) have quantified the evaporation in a semi-arid region of Spain, and they estimated that the evaporation loss could reach 8% of the water stored. As most part of France has a more humid climate, it can be considered that the loss will be lower in France, and that the stored water volume should decrease by less than 8% due to the evaporation loss."

7) Also regarding pond size, and as noted in the discussion, power law relationships are usually utilized for area-volume relationships of such tanks. Although the authors indicate awareness of such relationships, it is not clear why they used the simpler geometric relationship for estimating tan

We did not use area-volume relationships, because it was not clear if the relationships used in South Africa, America or Australia could apply in France. Indeed, the regulation in France is not the same for the dams that are deeper than 5 m, and most of the small farm dams have a depth smaller than 5m. The data collected on 171 small farm dams in south western France lead to an average depth of 3m, as shown in the figure below. For these reasons, we used a linear relationship.

To make this point clearer, the text was modified as follow

- section 2: "*An average value of $d_w = 3$ m was chosen, as it is the average depth of a short database referencing 171 small farm dams in south-western France, and as it is below the 5 m for which an annual survey of the dam structure is required.*"
- discussion: "*However, the depth of 3 m was used as it corresponds to the aver-*

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age depth of 171 small farm dams in south western France, and it is thought to be more appropriate to the France context."

References

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Histogram of the depth of 171 small farm dams in southwestern France

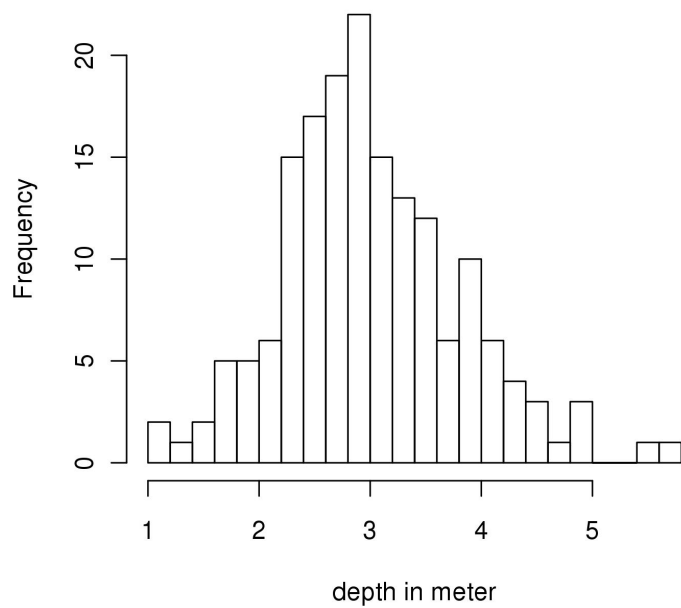


Fig. 1. Histogram of the mean depth of 171 small farm dams in southwestern France

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