Authors' Response

We would like to thank the reviewer for his constructive comments on the manuscript. We have considered the reviewer's comments and provide the following responses.

Statistical Representativeness

This study was designed to investigate the claim frequently made by non-scientific bodies that sand dams "revitalize the entire ecosystem." This is a claim sometimes repeated, although to a lesser extent, in the introductory sections of sand dam journal articles, but the current body of literature has not tested nor necessarily supported this claim. We do not intend to dismiss the existing sand dam work of various researchers. Rather, we want to challenge the unverified claims about sand dams made by invested parties, primarily NGOs. In having built our study on the foundations laid by the handful of published sand dam studies, we recognize and value the contributions of prior studies. We have altered the language of our primary objective so as to make clear that we are not dismissing the scientific work published to date but rather investigating the claims made by nonscientific bodies.

We thank the reviewer for drawing our attention to the broad conclusions in the manuscript that were not adequately supported by the discussion and/or strength of the data. In some instances, we agree that the language should be softened to ensure that we do not make claims that cannot be fully backed by the literature and statistical representativeness of the data. We will include additional discussion in the manuscript to support some of the conclusions that we believe are justified and adjust other conclusions to ensure they align with the representativeness of the data collected.

Modelling Efforts and Conclusions

An important distinction must be made concerning the motivation for developing a water balance model. The field data of the groundwater levels around the sand dams provide how much water the sand dams are losing over time. The model is being employed to inform the estimate of the various *causes* of those losses. This distinction will be clarified in the article before publication. The reviewer's issues with the model are addressed by number.

1. **The model calculates Qout based on the other terms, it therefore accumulates all errors in Qout, including errors because of terms not included in the model**
   There is uncertainty in the model, because the water balance is a simplified representation and the forcing data (FLDAS) is largely modelled data itself. Despite the uncertainty, the authors are confident that the relative magnitude of the terms in the model is reliable. The relative magnitude of the terms is the primary focus of the conclusions drawn from the model. We will add an explicit statement noting the uncertainty in the model.
2. **I assume from figure 7 that the authors start the dams "full". This is not made explicit in the article.**
   The analysis displayed in Figure 7 begins in the middle of the rainy season, so it is assumed that the sand dams are full at this point. However, this will change as a result of our model changes resulting from point 3, below. A sentence indicating the initial condition of the model will be added to the paper.
3. **The inflow term 0.038CP(t) accounts (I think, not made clear) for the amount of rain water that falls on the dam itself and is subsequently stored? I would argue that during a rain event all water from upstream would be routed over the stream-bed thus re-filling it. The 0.038 term from Aerts 2007 relates to the total amount of water a sand dam saves from annual**

discharge to see if dams have an impact on downstream water availability. This factor cannot be used as the authors do.

You are correct. The 0.038 term, hereafter capture ratio, from Aerts (2007) is the maximum proportion of annual discharge that a sand dam is expected to capture and store. In the water balance model proposed in the manuscript, the inflow term, 0.038CP(t), accounts only for the runoff that is expected to occur from the study areas indicated in manuscript Figure 1c,d. The area included in the model, therefore, is greater than the dam itself, but smaller than the upstream watershed. The watershed upstream of the Chididimo sand dam is 3.3 km^2 and relatively uniform. This allows the watershed to be modelled relatively well using the rational method for overland flow with a capture ratio of 0.038. The watershed upstream of the Soweto sand dam, however, is 262.1 km^2 and includes commercial farmland and an 18.6 km^2 wetland area. The Soweto sand dam is much too small to capture 0.038 of the runoff generated by such a large watershed. To more accurately represent the volume of water captured by the Soweto sand dam, the capture ratio would need to be reduced to around 0.00025 and adjusted for seasonal variability. However, such a methodology seems somewhat speculative, and we would prefer to be consistent in our methodology. In summary, the inflow term proposed in the water balance model is insufficient for accurately representing the volume of water captured by the Soweto sand dam. To address this issue, we initialized the water balance at the week of last rainfall. Therefore, there are no inflows to the theoretical model. The model now solely describes the loss factors, which is our primary interest (see Eq. 1 and Fig. 3, below).

4. **The 0.15 factor from Kumar 2018 relates to the percentage of evap that is canopy evap in the Noah LSM, which, if I recall correctly, was not calibrated for the region that the authors use it for. I would guess that on the African regions of interest here, the amount of canopy versus other evap would be different.**

   While the Noah LSM may not have been calibrated for East Africa, there are examples of Noah LSM being used over East Africa (Anderson et al., 2012; Yilmaz et al., 2014). Further, the evapotranspiration (ET) data used in the theoretical model presented in this paper is from FLDAS. The iteration of FLDAS used was developed based on the Noah LSM, but is specifically designed for use in sub-Saharan Africa (McNally et al., 2017). Furthermore, we believe the 0.15 factor for ET partitioning described in Kumar et al. (2018) to be appropriate. The climate in Dodoma, Tanzania is classified as hot semi-arid, which is also the climate in parts of the southwestern US and northern Mexico. From the figure below, included in the Kumar et al. (2018) paper, you can see that the canopy ET partition fraction for much of the southwestern US and northern Mexico falls between 0.1 and 0.2.

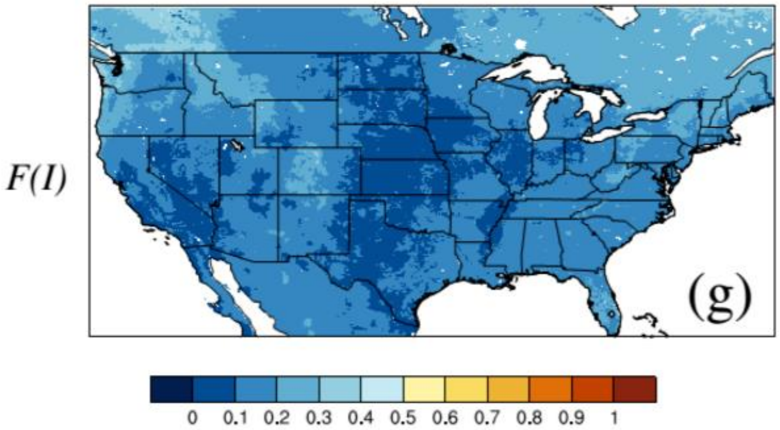

Figure 1: Mean of the ET partition fraction of canopy ET (unitless; from Kumar et al., 2018).

We recognize that the 0.15 ET partition fraction may not be perfectly accurate, but a study such as Kumar et al. (2018) has not been performed for East Africa. There is no better estimate available.

To more accurately represent the amount of water lost to ET within the control volumes, the ET will be multiplied by a factor of 0.85 for the area within the sand dams and will be multiplied by a factor of 1 outside of the sand dams. There is potential canopy ET outside the sand dams but within the control volume.

In addition, we realize that our manuscript is not clear on the size of the control volume to which the theoretical model is applied. Figure 2, below, provides the control volume for the Chididimo and Soweto sand dams. The control volume includes the sand dam and all area enclosed by the water table monitoring wells (WTMW) installed around the study area. Figure 2 will not be added to the manuscript, but a statement clarifying the extent of the control volumes will be added.

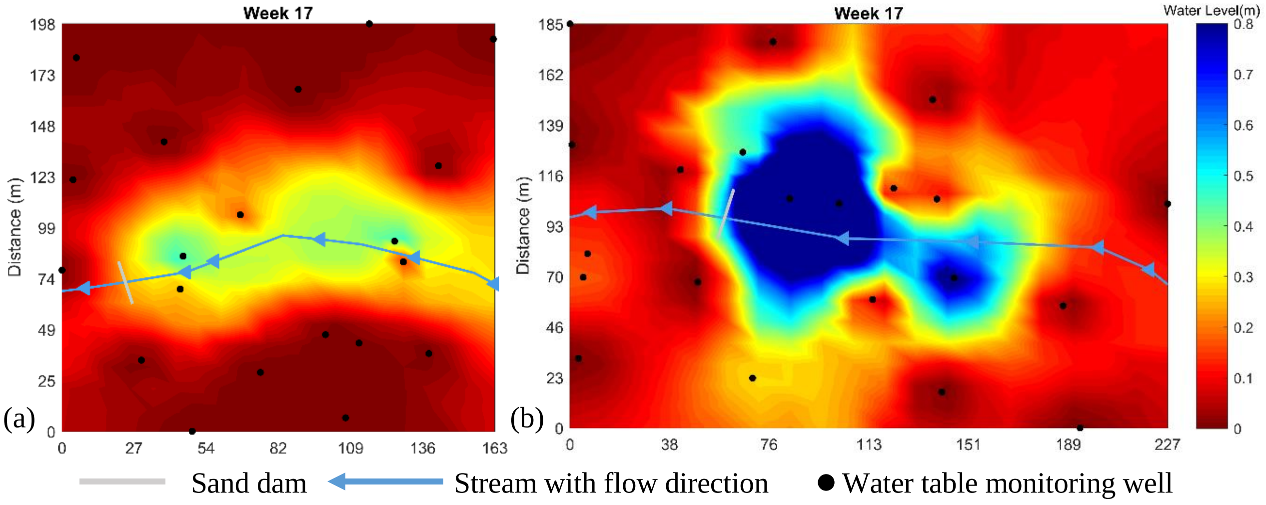

Figure 2: Height of subsurface water around the (a) Chididimo sand dam and the (b) Soweto sand dam.

5. **The Qcomm term is estimated based on conversation with locals. This is understandable given the constraints of the research, but introduces a very large uncertainty. In my own research we observed that some people living close to the dam would, against the deal with the entire community, use a machine pump to irrigate their lands from the sand reservoir, draining the reservoir very fast (Hut 2008).**
   We appreciate and understand the concern regarding the uncertainty of the community withdrawals variable. We will add a sentence to the manuscript indicating that the estimate of community withdrawals has an unknown degree of uncertainty. We, however, have no reason to believe that the community members were engaging in machine pumping of the water. The Soweto sand dam did have many areas under cultivation near the dam, but we did not see any evidence of machine pumping. Also, the community water group was very strict with its members regarding withdrawals under the guidance of the local chairman, including such measures as locking access to the hand pump. The Chididimo sand dam was much more difficult to access, and only had one small area nearby under cultivation. These reasons coupled with the lack of evidence lead us to believe that machine pumping was not a significant factor in the rate of water loss in the Soweto and Chididimo sand dams.

Given the above, Eq. (1) will be modified to:

$$Q_{out,dry\,season}(t) = -\alpha \times E(t) - Q_{sb}(t) - Q_{com}(t) \tag{1}$$

Where $Q_{out,dry\ season}$ is the rate of water loss from the sand dam after the end of the rainy season, $E(t)$ is total evapotranspiration modified by α, which is 0.85 for the area within the sand dam and 1 for the area outside of the sand dam, Q_{sb} is baseflow-groundwater runoff, and Q_{com} is the community's water use. Eq. (1) is integrated over time and subtracted from the volume of water in the control volume at the end of the rainy season to create a theoretical volume of water curve for the sand dam area.

Given the changes to Eq. (1), Figure 7 is modified to:

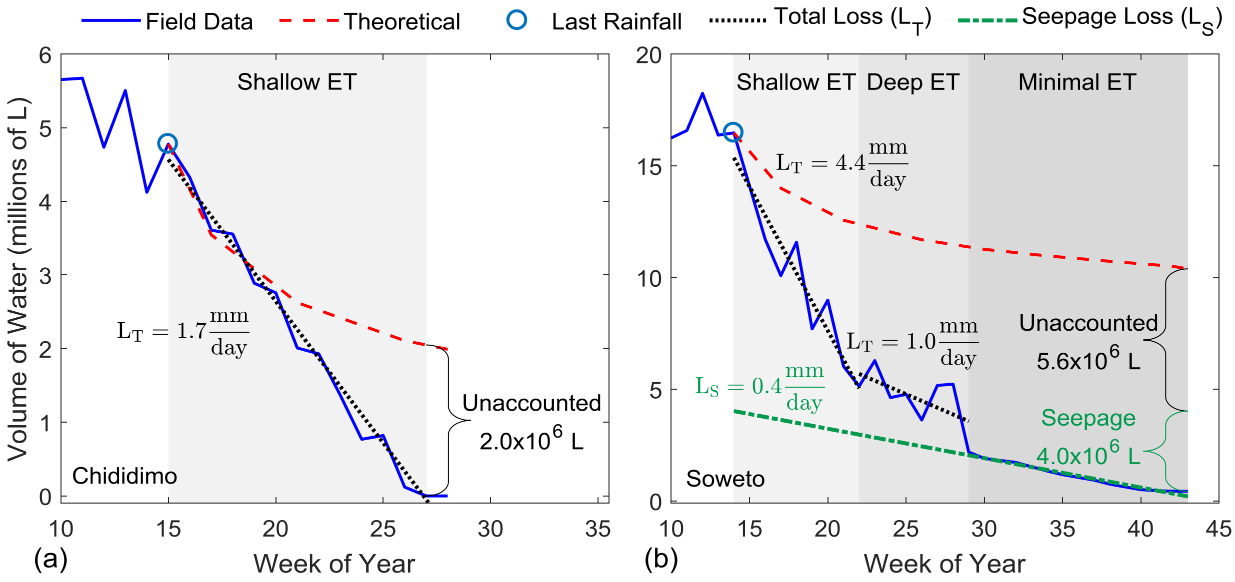

Figure 3: Volume of water in the area enclosed by the WTMWs of the (a) Chididimo and (b) Soweto sand dams. The field data line shows the volume of water in the study area during the specified week. The theoretical line, initiated at the end of the rainy season, shows the theoretical amount of water in the study areas, calculated by integrating Eq. (1). The theoretical line accounts for losses due to evapotranspiration, baseflow-groundwater runoff, and community use.

The changes to Eq. (1) result in the following loss partitioning (summary of changes, not for inclusion in manuscript):

Table 1: Sand dam stored water loss partitioning during the dry season

Loss Partition (%)	Chididimo		Soweto	
	Old Eq. (1)	Updated Eq. (1)	Old Eq. (1)	Updated Eq. (1)
Evapotranspiration	85	53	51	35
Baseflow-groundwater runoff	1	1	1	1
Community use	5	4	8	4
Seepage	-	-	-	25
Unaccounted	9	42	40	35

From Table 1, above, you can see that the loss partitioning for the Chididimo sand dam did not change much as a result of updating Eq. (1), with the exception of the unaccounted fraction which is still understood to be primarily ET losses. The loss partitioning for the Soweto sand dam did change significantly with the inclusion of seepage losses. The Soweto sand dam does lose water as a result of seepage, as evidenced by the scoopholes community members dig just downstream of the dam from which they collect water. Community members did not exhibit the same behavior at the Chididimo sand dam, therefore we do not believe that there is significant seepage occurring at the Chididimo sand dam. At Soweto, the community members expressed an inability to abstract water from the sand dam after approximately the 30th week of the year. Therefore, we believe that the water lost from the Soweto sand dam after the 30th week is likely due primarily to seepage losses. Assuming seepage is relatively constant, we can extrapolate this portion of the plot back to the end of the rainy season and get an estimate of total seepage losses from the Soweto sand dam during the dry season (Fig. 3b). There is likely minimal ET loss occurring after the 30th week, because the water is deep underground at that point (Hellwig, 1973).

Figure 4 shows partitioning changes in the water lost from the study areas during the dry season. This figure will be added to the manuscript with additional explanatory text.

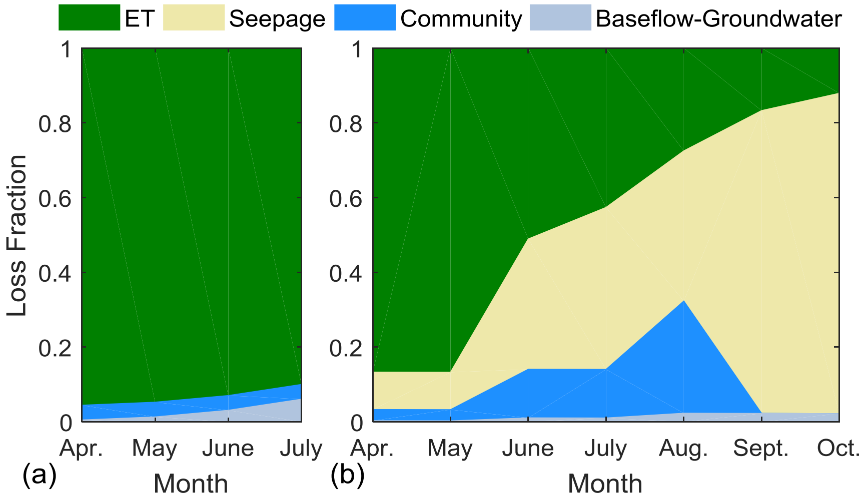

Figure 4: Fractional causes of water lost from the area enclosed by the WTMWs of the (a) Chididimo and (b) Soweto sand dams.

In regards to your estimate of the mm/day rate of evapotranspiration from the sand dams, the estimate is quite high due to the misunderstanding about the size of the control volume from which the field data line is determined for Figure 3. From Figure 2, above, there is clearly a great deal of seepage from the sand dam through the streambanks, so the area from which evapotranspiration is occurring is significantly greater than simply the surface area of the sand dams. The updated estimates for the rate of evapotranspiration losses from the Chididimo and Soweto sand dams are: 380 000 L/week and 1 117 000 L/week (slope of total loss-seepage loss, Fig. 3), respectively. With this understanding, the rate of evapotranspiration losses can be calculated as follows:

$$Total\ Loss\ Rate(L_T)\frac{mm}{day} = \frac{Slope\ of\ Total\ Loss\ Line\,\frac{L}{week}}{7\,\frac{days}{week} \times Control\ Area\ (m^2)}$$

$$Avg.\,Evap\ Rate\ \left(\frac{mm}{day}\right) = Total\ Loss\ Rate\,\frac{mm}{day} \times (Evap + Unaccounted\ Fraction)$$

$$Avg.\,Evap\ Rate_{Chididimo,shallow}\ \left(\frac{mm}{day}\right) = \frac{380\ 000\,\frac{L}{week} \times (0.52 + 0.42)}{7\,\frac{days}{week} \times (163\ m \times 198\ m)} = 1.56\,\frac{mm}{day}$$

$$Avg.\,Evap\ Rate_{Soweto,shallow}\ \left(\frac{mm}{day}\right) = \frac{1\ 300\ 000\,\frac{L}{week} \times (0.35 + 0.35)}{7\,\frac{days}{week} \times (227\ m \times 185\ m)} = 3.09\,\frac{mm}{day}$$

The above evapotranspiration rates are in general agreement with the sand dam sub-surface evaporation rate of 2.4 mm/day found by Borst and de Haas (2006). It should also be noted that the Soweto estimate is valid only for the rate of ET when the sand dam is relatively full. As is clear in Figs. 3b and 4b, the rate of ET decreases as the volume of water in the sand dam decreases.

Additional References

Anderson, W. B., Zaitchik, B.F., Hain, C.R., Anderson, M.C., Yilmaz, M.T., Mecikalski, J., and Schultz, L.: Towards an integrated soil moisture drought monitor for East Africa. Hydrol. Earth Syst. Sci., 16, 2893–2913, doi:10.5194/hess-16-2893-2012, 2012.

Yilmaz, M. T., Anderson, M.C., Zaitchik, B., Hain, C.R., Crow, W.T., Ozdogan, M., Chun, J.A., and Evans, J.: Comparison of prognostic and diagnostic surface flux modeling approaches over the Nile River basin. Water Resour. Res., 50(1), 386–408, doi:10.1002/2013WR014194, 2014.