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Discussions

Interactive comment on "Interplay of changing irrigation technologies and water reuse: Example from the Upper Snake River Basin, Idaho, USA" *by* Shan Zuidema et al.

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We would like to start by thanking the referee for their thoughtful and generous comments on our manuscript. We found the feedback constructive and discuss how these comments will inform the revisions of our manuscript.

The referee astutely recognized that we did not include a representation of Jevon's paradox in the context of irrigation efficiency, even though we highlight how it has affected water management in the USRB in the past (P2,L11). Though we don't believe that it is feasible for us to make such a representation, it is important to discuss the effect of a positive correlation between consumptive use and efficiency and plan to

provide such a discussion in the final paragraph of section 4.1 (P14,L21). There are two competing incentives at work here with regards to water withdrawal reductions as CIE increases: on the one hand, prior appropriation doctrine requires that water rights holders use their full water right beneficially, essentially encouraging constant levels of water withdrawal regardless of CIE. On the other hand, frequent droughts, the collective action of irrigation districts, and legal agreements between water user organizations outside of the prior appropriation system, all work to incentivize reduced water withdrawals when possible (Gilmore, 2019). Moreover, a settlement between surface and groundwater irrigators (IDWR, 2015) details specific requirements for ensuring stable aquifer head for both irrigation and downgradient outflow from springs. For the simulations shown here, a reduction in water withdrawals as CIE increases is not completely unrealistic due to the documented, incentivized, and coordinated effort underway in the USRB to stabilize aquifer levels.

We would be happy to accommodate the referee's comment regarding a discussion of seasonality of discharge from springs and reservoir storage. Our revised manuscript would more clearly relate the timing of snowmelt and release through the cascade of reservoirs discussed at P10,L4-10 as the reason for reservoir volume misfit. The seasonal dynamics of spring outflows are highly damped in the model because of the lumped approach by which we simulate groundwater storage, and this deserves mention. Though we understand the mechanisms that control this misfit, we expect a thorough explanation of these will be distracting in the context of the manuscript. Still, we agree that it prudent and appropriate to state (in the results section) that a) seasonality does not affect internal functioning of groundwater abstraction, and there is no evidence that seasonal variation in the water table creates widescale problems for groundwater pumpers, and b) springs discharge to a point on the Snake River downstream of major surface water abstractions in the basin, so seasonality of discharge from springs does not affect surface water irrigators in the USRB. Our consideration of downstream flow and availability to downstream irrigators only focuses long-term effects of changing flow at annual time-scales.

We agree that the Distribution Uniformity (DU) parameter, which controls the excess water each technology applies to fields, is critical in our study and will expand on the definition (e.g. Burt et al. 1997) and use of the concept in our revised manuscript. The DU parameter controls the amount of non-consumptive returns from irrigation, which then determine the amount of enhanced aquifer recharge (EAR) required for aquifer stabilization. Therefore, the referee is correct to point out that uncertainty in these values may influence the quantitative results of our study. We note that the work of Jägermeyr et al. (2015) show that both crop yields and soil moisture deficit are fairly insensitive to a range of DU in the regions selected such that modest reductions in DU (increases in efficiency) would have little adverse impact on cropping outcomes, but increases in DU (decreasing efficiency) would incur no benefits. We agree that this is a valid point, but we are unclear what to do about this uncertainty. Consider two cases. Case 1, DU are selected such that they are lower for sprinkler and surface irrigation so that crop beneficial consumption is virtually unchanged, however incidental recharge is reduced so that EAR must therefore increase to ensure aquifer stabilization. This may be a practical scenario for system management; however, it is difficult to reconcile with observations from the USRB because our model already is biased low for gross irrigation abstractions and such a parameterization would deviate further from observations. Now for Case 2, the DU parameters could be increased such that the system is less efficient and increasing incidental recharge offsets a need for a certain amount of EAR. Although this would better fit the high rates of gross irrigation abstraction, it does not seem likely that a heavily regulated and expensive water distribution system would permit for such inefficiencies. Furthermore, such a parameterization without an empirical basis (as provided by the analysis of Jägermeyr et al. 2015) would be overfitting the model to the limited observational data we have. Our final point on this topic is a general one. The DU parameter is but one of several very uncertain parameters that have an identical effect on the system outcome including vertical saturated hydraulic conductivity underlying canals, the existing quality (anecdotally poor) of canal liners, the proportion of active irrigation technologies, and infiltration rates of soil. Uncertainty

in these parameters likely overwhelms that of the DU and a substantial portion of the range of the cumulative effect is characterized by our scenarios. Still the importance of this parameter, and the capacity to improve a number of factors associated with irrigated water associated with improved water management (practices that would actually reduce the DU) will be more clearly identified in the conclusion of the revised manuscript.

Yes indeed, another reviewer also identified our need to define effective irrigation efficiency (EIE) in the manuscript which was an oversight. While Haie and Keller (2008) define EIE using a water quality discount in certain classes of models, they also define a quantity only case that considers all incidental returns as available for further use so that the denominator used in the calculation of EIE reflects only the blue water abstracted for irrigation:

$EIE=B/(G-R)$

where B, G, and R represent beneficial consumption, gross irrigation abstraction, and reused irrigation abstraction, respectively, all in units of volume per time. This equation and the equation for classical irrigation efficiency will be included in the discussion of hydrologic fractions in Section 2.2 of the revised manuscript.

We thank the referee for pointing out the needed technical corrections.

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