Reviewer 2

The manuscript "Influence of irrigation on root zone storage capacity estimation" assesses the impact of global irrigation practices on root zone water storage capacity. The findings are quite interesting suggesting a general reduction in storage capacity particularly for agriculturally areas.

The paper is generally well written and fairly easy to understand given the theoretical nature and complexity of the topic. I find it suitable for publication in HESS after addressing some concerns.

We would like to thank the referee for the comments. We appreciate the time and effort taken to read our manuscript in detail and to provide us the very useful and interesting thoughts on our research. We will take the comments into account when revising the manuscript.

We have separated the different comments (shown in *italic*) and have written our replies below. Text in the original manuscript is shown in '*italic*' and revised text in '***bold***'. Unless differently stated, line numbers mentioned in our reply refer to the original manuscript version.

Comment 2.1

My main struggle when reading the manuscript was the lack of potential consequence of their estimations. For example, what are the consequences for landscape scale land-use and land management? I.e. you determined a decrease in root water storage capacity with irrigation, but would it not be more meaningful to try to explore "best" irrigation practices for a hydrologically resilient agriculture? I would prefer some calculations, but at least this issue should be thoroughly discussed.

From an agricultural perspective it is indeed logical to explore the optimal irrigation practices in a way the crops can optimally function. However, we believe that the memory method as presented here is suitable for large-scales, such as catchments, but it may be too simplistic for the scale of agricultural fields. The aim of this study was to quantify the influence of irrigation on the root zone storage capacity at catchment scales, while wider implications for landscape scale land-use and land management are beyond the scope of this research.

Comment 2.2

Discussion: in general the discussion is fairly short and not exactly spiked with literature comparison and contextualization. This could be improved. Aside from the suggestion above, one discussion point could be the process-based mechanisms underlying reduction in root water storage capacity. In the introduction the authors relate this mainly to anatomical changes in the rooting system, i.e. shallow and less dense root system under irrigation. However, plants react to changes in water input regime in more ways than anatomical adjustments. E.g. how does changes in hydraulics or generally differences in hydraulics between species affect Sr? Is it, i.e., possible that adjustments or species specific differences in plant maximum water potentials (ψ) affect Sr and how?

We agree that we focused only on vegetation root responses to irrigation, without mentioning other plant adjustments. Plants react to irrigation activities also by changes in, for example, stomatal aperture (Chaves et al., 2016) or root hydraulic conduction (Gullo et al., 1998). In the discussion, we will also elaborate more on the process-based mechanisms underlying the here found reduction of root zone storage capacity as a result of irrigation. We will do this by adding the following lines after L239:

"…of vegetation transpiration (Fig. 7). ***The reduction in S_r in catchments with irrigation was expected following that the memory method is based on the theory that vegetation will invest less in roots if sufficient water is available (Guswa et al., 2008). The observed changes in S_r are here attributed to***

changes in the vegetation roots, as they are directly related to the size of S_r. Additionally, adaptations at the plant scale associated with irrigation, such as adjustments in stomatal aperture (Chaves et al., 2016) and root hydraulic conductance (Gullo et al., 1998), are also implicitly related to changes in S_r."

Specific comments

Comment 2.3

LL25: actually phenological development especially in croplands is pretty important and can easily outrule other influences.

LL25ff: this definition of Sr is dominated by physical objectives and does not consider plant regulation at all, same goes for the description of T (transpiration) regulation. This lacks an understanding of physiological and ecological processes that regulate T (transpiration) and I find this troublesome.

We completely agree that phenological development also plays an important role in vegetation transpiration, though mostly at individual plant level. However, in this study we focus on entire ecosystems with mixed vegetation species, and approach the catchment vegetation transpiration from a large-scale water demand and supply perspective.

The definition of S_r as the 'maximum volume per unit square of subsurface moisture that is accessible to roots of vegetation for uptake' is indeed mostly based on a physical objective, namely vegetation water supply at catchment scales. With respect to vegetation adaptivity, it is important to distinguish between individual plants, and the collective of individual plants within an ecosystem. Individual plants respond to droughts through for example root biomass adjustments, anatomical alterations, and physiological acclimations (e.g. Brunner et al., 2015). This adaptive capacity of individual plants depends on vegetation species (Zhang et al., 2020). Here, we focus on catchment scale where the root zone storage capacity represents the adaptation of the vegetation, i.e. the collective of all plants in the entire catchment with respect to subsurface water availability.

We will clarify this in the introduction in L25:

"The amount and timing of vegetation transpiration ***at catchment scales*** *is* ***largely*** *controlled by the interplay between seasonal energy and water availability signals (Gentine et al., 2012).* ***At individual plant scale, plants regulate transpiration also by root biomass adjustments, anatomical alterations, and physiological acclimation (e.g. Brunner et al., 2015), depending on vegetation species (Zhang et al., 2020). However, at the ecosystem scale, which represents the collective of individual plants,*** *the subsurface water removal by transpiration is regulated by the liquid water input and by the available subsurface water buffer. This water buffer, the root zone storage capacity (S_r), is defined as the maximum volume per unit square of subsurface moisture that is accessible to roots of vegetation for uptake (Gao et al., 2014)."*

Comment 2.4

LL44: do you truly mean evaporation or evapotranspiration?

We acknowledge that various perspectives exist concerning the definition of evaporation vs evapotranspiration. Here we mean evaporation, defined as the sum of transpiration, soil evaporation, and interception evaporation. We will clarify L44 as follows:

"…seasonal signals of precipitation and evaporation, ***here defined as the total of transpiration, soil evaporation, and interception evaporation, following the terminology proposed by Savenije (2004) and Miralles et al. (2020).****"*

Comment 2.5

Fig 2 and methods section: Why do you specifically need two years? Also: You start the hydrological year with the day of highest water availability. But how do you deal with consecutive years varying in precipitation regime? Or do you just define this for the starting point?

Figure 2 only shows two years of a timeseries to illustrate the method, but all catchments have at least ten years of data available. We will clarify this in the caption of Fig. 2 as follows:

"…(b) An example time series of S_s, S_d and I based on Eqs. (1-6) with Δt_d the length of the deficit period (days), and S_s (ts1) the surplus storage at the end of the surplus period. ***Note that this time series represents only two years to illustrate the method, while all catchments have at least ten years of data."***

We start the hydrological year on the day of highest water availability, but this is only used as starting point on the first day of the full timeseries. This means that during consecutive years with varying precipitation regimes the storage deficits do not necessarily recover each year. We will clarify this in L120 as follows:

*"In Eq. (1) t0 corresponds to the first day of the first hydrological year and τ to the daily time steps ending on the last day of the last hydrological year. Our hydrological year starts the first day of the month after the wettest month, which is defined as the month with on average the largest positive difference between monthly mean P and Ep****. At t0, the starting point of the analysis, S_d=0."***

Comment 2.6

Fig. 4 and 6: the way the figure is plotted in the preprint this is very hard to read given the size and color palette.

For Fig. 4 we will change the colormap to the matplotlib 'cubehelix' colormap, which is colorblind-proof, and covers a relatively large lightness-range. See the updated figure in Fig. C1.

For Fig. 6, we believe that the here used colormap represents our intentions with the figure well, as we want to emphasize on the catchments where the ΔS_r is relatively large (the darker, the larger), while still showing the catchments with small ΔS_r (yellow).

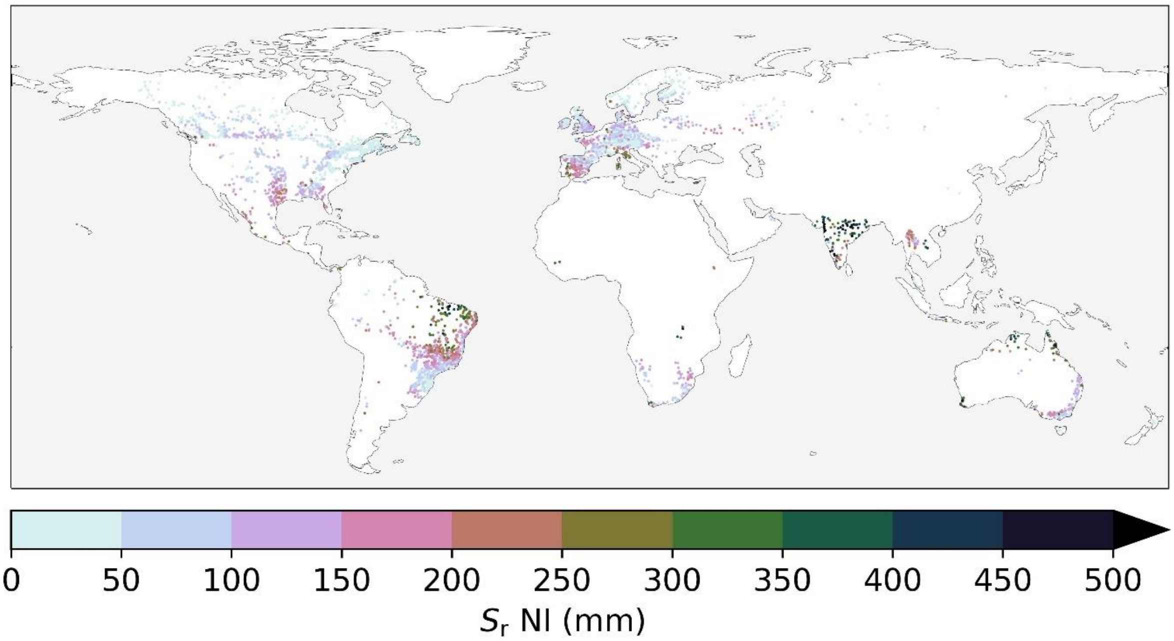

Figure C1. Catchment Sr for the No Irrigation (NI) case, with dots representing catchment outlets. Similar figures for the IWU and IAF cases are presented in Fig. S1.

References

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