Comment:

This manuscript presents the effects of partial deforestation on water storage and water ages in the German Wüstebach catchment. For this study, the authors performed water balance analyses and modelling exercises based on 7 years of hydrometric and water stable isotope data. One major finding of the study is that the vegetation-accessible storage volume in the unsaturated zone, SUmax*, was significantly reduced after the partial deforestation; the authors hypothesize that this reduction in *SUmax* can largely be explained with young water being routed quickly to the stream during wet conditions, so that less water reached the unsaturated zone *SU*.

The paper is well written and the figures are informative. I only have some minor comments and questions that the authors should address.

Reply:

We highly appreciate the reviewer's positive assessment of our manuscript and thank her/him for the thoughtful detailed comments.

Comment:

The physical meaning of *SUmax* not fully clear to me: its definition in the introduction is "water-filled pore volume between field capacity and permanent wilting point that is within the reach of active roots". This suggests that *SUmax* depends on water content in the soil and the active rooting depth. Does this mean that *SUmax* will decrease when water influx is reduced and/or roots become shorter? Then, the major result of the study (i.e., *SUmax* is reduced after deforestation; L421-424) is not surprising but rather expected because fewer roots will lead to a smaller catchment-average active rooting depth.

Reply:

*We believe that our addition "water-filled" made the definition unclear. $S_{U,max}$ is the "pore volume between field capacity and permanent wilting point that is within the reach of active roots". As such it describes the **maximum** (i.e. the upper bound, "capacity") possible water volume that can be **held** against gravity (i.e. above field capacity) **and** that can be **accessed** by vegetation.*

Indeed, $S_{U,max}$ is completely independent of the actual water content in the soil at any time. For practical purposes, it is can be considered constant over short time-scales < 2-3 years (although of course in reality it is continuously changing and adapting, albeit at mostly very low rates). In more humid climates, $S_{U,max}$ is typically smaller than elsewhere (e.g. Gao et al., 2014) – when there is constant water supply, e.g. when it is frequently raining, these frequent rains sustain rather near-surface soil water contents for much of the year. Vegetation therefore does not need to develop an extensive root-system to be able to access sufficient water. The opposite is true e.g. for more arid environments. In other words, when the water influx is reduced, $S_{U,max}$ will need to increase if vegetation wants to survive. Vegetation does so by developing more extensive root systems (either by individual plants growing deeper/denser roots or by specific, not sufficiently adapted plants dying and being replaced by more adapted ones). Indeed, the major result of this study is not surprising – fewer roots lead to a smaller catchment-scale root-accessible pore space $S_{U,max}$.

*As actual root observations are very scarce in space and time, the critical questions for hydrology are: **(1) how large is this root-accessible pore space at the catchment scale** and **(2) how much does it change after deforestation?***

We showed that $S_{U,max}$ can not only be quantified at the catchments-scale (as a few previous studies also suggested, e.g. Gentine et al., 2012; Gao et al., 2014) but that also its post-deforestation change can be quantified and that this change is a plausible explanation for younger water ages during wet conditions.

We will clarify the definition of $S_{U,max}$ in the revised manuscript.

Comment:

L135: How many measurements of rooting depth are available to justify the general assumption that the maximum rooting depth across the catchment is 50cm? What is the depth of the groundwater table and is it possible that capillary rise from the groundwater supplies these shallow-rooted plants?

Reply:

There is only anecdotal and indicative information about root-systems in the study catchment. However, there is no indication of systematic and wide-spread presence of deeper roots.

In the riparian zone, the groundwater table can reach the surface for a few days during the wet winter months, when transpiration is very low and which is therefore largely irrelevant for the estimation of $S_{U,max}$. During the growing season, which is critical for $S_{U,max}$, the groundwater table remains well below 1 m most of the time in the riparian zone, as shown by Bogena et al. (2015) and it can be expected to be considerably deeper on the hillslopes.

It is indeed possible and likely that groundwater sustains soil moisture levels and thus indirectly supplies vegetation. This is explicitly accounted for in our model as flux $R_{S,R}$ (Figure 3; Equations 11, 13 and 24; l.261-262).

We will clarify this in the revised manuscript.

Comment:

Are there any additional data that support your claim of a large groundwater storage in the Wüstebach catchment? It is surprising to me that no groundwater table and soil moisture observations have been considered for explaining many of the processes you propose.

Reply:

*We agree that such a large mixing volume is indeed surprising and apart from the tracer observations we do not have direct evidence for the underlying reasons. However, we discuss potential explanations for that in the original manuscript. Although a "large groundwater storage" **can** be the cause, it **does not necessarily have to be**. One alternative hypothesis is that old groundwater may enter the system from outside the defined catchment and replace (i.e. push out) younger water as unobserved groundwater export (l.606-621).*

In case there is no such groundwater exchange, something needs to buffer the high precipitation variability to the much dampened pattern observed in the stream tracer compositions, which do exhibit almost no fluctuations that go beyond measurement uncertainty. Following our current, rather well-developed understanding of tracer hydrology, such an effect can almost exclusively be caused by a large water storage volume that allows for sufficient "mixing" (e.g. Maloszewksi and Zuber, 1982; McGuire and McDonnell, 2006).

Based on our reply to the previous comment and thus assuming a conservative upper bound of catchment-average depth of the groundwater table at ~ 5 m (assuming that the lowest groundwater table at each point in the catchment is at the elevation of the nearest stream), porosity of the silty clay loam (Bogena et al., 2018) soil of 0.4 and field capacity at a relative pore water content of 0.5 suggests an upper storage limit ~ 1000 mm in the unsaturated zone. As no further significant storage volumes besides the unsaturated zone are known and in case there is no significant exchange of groundwater (see above) in the study catchment, only the groundwater remains as the required storage volume.

To answer the second part of the above comment, it is true that in the study catchment a lot of data is available. However, these data are largely inferred from point-scale measurements. Incorporating this information in catchment-scale models is challenging if not impossible to do in a meaningful way. For example, while our root-zone reservoir S_U represents the catchment-average water content in the root-zone, which soil moisture observations should this be compared to? The ones in 5 cm depth? In 10 cm? 50 cm? Or an average of that? What if there are in reality no roots at that depth at a given location? To avoid introducing a further level of assumptions, we therefore did not make use of point-scale measurements in our study.

We will clarify that in the revised manuscript.

Comment:

How dry, drying, wet and wetting-up periods were defined (L545, L561, Fig. 8)?

Reply:

We imposed four thresholds to classify time steps along a spectrum to these periods. Briefly, periods with flows above Q_{25} were classified as wet, periods with flows below Q_{75} were defined as dry, increasing flows between Q_{25} and Q_{75} as wet-up period and receding between Q_{25} and Q_{75} as drying.

Comment:

Fig. 8 and Sect. 5.3: How was the daily young water fraction calculated and what is the associated uncertainty? Are your interpretations robust with respect to the uncertainties in *Fyw*?

Reply:

The daily young water fractions were extracted from the daily travel time distributions as the fraction of water volumes that is younger than 3 months (i.e. 32 days). Due to the lack of computational capacity we were unfortunately only able to provide uncertainty estimates for the long-term average $F_{yw,avg}$ as shown in Figure 8a and 8b in the original manuscript. We will clarify this.

Comment:

L434: From Fig 2d it is hard to see how well the model simulated theδ18O time series because the data points cover each other too much.

Reply:

We agree that Figure 2 will benefit from some adaptations. Specifically for Figure 2d we will therefore (1) aggregate the precipitation tracer composition to monthly values and (2) add an additional subplot with a zoomed-in version for one individual year pre- and one year post-deforestation.

Comment:

Fig 8d, c: It is not clear to me, which data points were used to obtain these regression lines? Especially the dark-blue regression lines (wet conditions) do not seem to fit the blue data points at all, and thus, the associated regression slopes should be considered with caution (e.g. in L588).

Reply:

We agree that the individual groups of data points are difficult to distinguish. To nevertheless allow the reader to better assess the strength of these relationships we will add the associated R^2 and p-values.

References:

Bogena, H. R., Bol, R., Borchard, N., Brüggemann, N., Diekkrüger, B., Drüe, C., ... & Missong, A. (2015). A terrestrial observatory approach to the integrated investigation of the effects of deforestation on water, energy, and matter fluxes. Science China Earth Sciences, 58(1), 61-75.

Gao, H., Hrachowitz, M., Schymanski, S.J., Fenicia, F., Sriwongsitanon, N., & Savenije, H.H.G. (2014). Climate controls how ecosystems size the root zone storage capacity at catchment scale. Geophysical Research Letters, 41(22), 7916-7923.

Małoszewski, P., & Zuber, A. (1982). Determining the turnover time of groundwater systems with the aid of environmental tracers: 1. Models and their applicability. Journal of hydrology, 57(3-4), 207-231.

McGuire, K. J., & McDonnell, J. J. (2006). A review and evaluation of catchment transit time modeling. Journal of Hydrology, 330(3-4), 543-563.