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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Catchment-scale groundwater recharge and vegetation water use efficiency" *by* Peter A. Troch et al.

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"This research proposed an estimation method of catchment-scale long-term average recharge rates based on simple catchment characteristics with the aim to provide a connection between groundwater recharge, aquifer discharge to streams during dry periods, streamflow regime type, and vegetation water-use efficiency. It was achieved by quantifying the relationship between the Horton index (HI) and average base flow and regionalizing HI using catchment characteristics. Although the scope of the manuscript (MS) is suited to Hydrology and Earth System Sciences (HESS), there are some scientific issues with the current MS that do not allow me to support its publication in HESS. Obviously, the quantified relationship between the Horton index, which is estimated from base flow, and average base flow is some kind of circular argument. The au-

thors have realized this foundational flaw (L497-499). They argue that it is meaningful to estimate average baseflow by predicted HI from climate and landscape properties (L500-502). But this does not help, using predicted or observed HI has nothing to do with the flaw in HIâĹijQb relationship. In fact, when reading the manuscript, there is always a question in my mind: may the similar performance be achieved if we predict catchment average base flow using climate and landscape properties directly? "

We thank the reviewer for taking the time to read and comment on our manuscript. As stated in the above comment, we recognize that the estimation of the Horton index requires estimates of baseflow through baseflow separation and analysis. To remind the reviewer, the HI was first proposed by Horton (1933) and interpreted as the fraction of infiltrated water that vaporizes back into the atmosphere. In other words, the complement of HI is the fraction of infiltrated water that is available for recharging the catchment aquifers. It is therefore an index of how much recharge can be expected on average, and thus directly linked to low flow dynamics that sustain riparian ecosystems. Following this logic, it does make sense to estimate HI from climate and catchment characteristics, such as aridity index, slope and elevation, and then relate the predicted catchment HI (without the need for baseflow analysis, as this information is mostly unavailable for ungauged catchments) to its long-term average recharge rate. The reviewer is probably correct that we could have done the regionalization with catchment characteristics directly, but that would not have allowed us to relate terrestrial ecosystem functioning to streamflow dynamics. Regionalization studies that are based on correlations between catchment properties and hydrological signatures are often hard to interpret physically, as the demonstrated correlations are not necessarily causations. We believe that we have made this argument clear in the existing text, but if this reviewer has more detailed suggestions on how to improve the readability of our manuscript, we are open to consider these.

"I also find the logic of the manuscript confused: 1) I cannot understand the role of STmax in the manuscript without which the main story almost has no change; 2) The relationship between Q50 and HI (or the relationship between Qb,obs and Q50) seems to be a branch of the story, but they are mixed up in the manuscript now, with some explanation but not clear at all."

Without more detail, it is hard for us to understand what exactly it is that confuses the reviewer regarding these two points. As to the first point, STmax is the annual maximum total storage in a catchment, and in our manuscript we demonstrate that the HI is the best predictor of this hydrologic signature, thus expanding the findings of Arciniega-Esparza et al. (2016). The fact that the HI better predicts STmax hints to the possibility that HI is an important constraint on the dynamic storage of a catchment. This is no surprise given the definition of HI as mentioned above. As to the second point, we used Q50 to estimate average recharge rates and relate Q50 to the HI. Our results show that there is high and statistically significant (at 95% confidence level) correlation between those two variables, both in space and time, but also show that Q50 generally underestimates the average baseflow rates. We found that for our catchments, Q60 is a better estimate of average recharge rates, but before we suggest to use the HI-Q60 relationship to estimate regional recharge rates, more research is needed to see whether our findings can be confirmed in other catchments. We clearly address this issue in our Discussion section.

"L539-540: it seems contradictory with L464-468 where you have claimed the limitation of your method in poorly vegetated catchments. Additionally, an easy work to test the applicability of your method in different landscapes: to compare the estimation performance (e.g., RMSE in GW recharge) in well vegetated and poorly vegetated catchments. But as shown in Figure 11, your method underestimated GW recharge at all catchments with GW recharge higher than 800 mm/year (usually with high vegetation cover according to figure 10)?"

L464-468 states: "This is generally the case in vegetated landscapes, but will obviously not the case in poorly vegetated arid catchments. Therefore, the proposed method cannot be used to estimateÂărecharge rates in desert landscapes (except, perhaps, in the

Sonoran Desert of the SW USA, which has significant green cover throughout the rainy seasons)". This statement refers to the fact that in well-vegetated catchments, most of the vaporization comes from transpiration, but that in poorly vegetated catchments, this is obviously not the case. L539-540 states: "vegetation water-use efficiency (the Horton Index) is a robust predictor for low flows and groundwater recharge in catchments with different types of climate, soils, geology and vegetation cover". We believe that this statement is generally true, but we will specify in the next version of the manuscript that poorly vegetated (desert) catchments are not included in this statement. "I have to say I find most analysis and conclusions (e.g., L430-433, L433-435, L450-452, Key Point (1) and (2)) in this research similar (or repetitive) with these in Arciniega- Esparza et al. (2016) and Voepel et al. (2011). It seems that most of their works are to prove previous findings without new perception or substantial contribution". Referring to our abstract and introduction, where the objectives of our study are stated, one of the objectives was to confirm/reject the conclusions of Arciniega-Esparza et al. (2016) in different climate and geological settings. Therefore, key points 1 and 2 list our results in comparison to that previous study and therefore can look repetitive, but are still needed to report our findings. Voepel et al. (2011) looked at how catchment characteristics can be used to predict HI, and we used his analysis to develop a predictive model to get the HI of the catchments independent of baseflow, and test how this predicted HI relates to long-term average recharge rates. It is therefore also logical that some of the materials reported in our study relate to some findings in Voepel et al. (2011). We believe there is nothing wrong to build on previous research.

"Figure 9: Please explain the meaning of red dotted line".

The red dotted lines in Figure 9 are the 95% confidence intervals of the linear regression. We will add that information to the new version of our manuscript.

"L249-253 and L291-293: We know what you mean. But please try to avoid contradiction in one manuscript".

These statements refer to the fact that the authors of the MOPEX database tried to guarantee to select catchments with minimum human impacts, but that no human impact is virtually impossible in USA catchments, and thus the possibility that one of the catchments used in our study is affected by pumping cannot be excluded. Since even this reviewer knows what we mean, we think we can leave it to this.

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