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Reply on RC1

Alemu Yenehun et al.

Author comment on "Spatial and temporal simulation of groundwater recharge and cross-validation with point measurements in volcanic aquifers with variable topography" by Alemu Yenehun et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-527-AC1, 2022

Response to the general comments forwarded by the referee:

English language improvements and corrections have been made including suggestions made by you in the revised version.

In the general comment as well as in the specific comments (in the attached manuscript of the referee), clarity about the objectives has been raised as the main limitation of the manuscript. This could be due to problems of us in explaining the main objectives as explicitly as possible which we thought we have done in the revised version that we will attach.

The main aims of this paper are:

Each recharge estimation technique has its own limitations, depending on the recharge mechanisms, the aquifer topographical setting, aquifer type (for example fracture vs porous soil aquifers, confined vs unconfined), aquifer geometry, etc. Hence, the effectiveness of recharge estimation techniques is varying, and thus in this study evaluation of the hydrological model (WetSpass) has been made (i.e. validation with measured point values though some variables are estimated in these methods too!!) for the Lake Tana basin having high topographic, variable slope, and comprising different volcanic aquifers. Such aquifer types are found in many parts of Ethiopia and is the major groundwater resources for the global water need. The WetSpass model applied in this study is a physically-based distributed hydrological model which gives spatially distributed spatial water balance terms including recharge. Yes, there are statistical interpolations for some of its input variables but the final spatial recharge and other water balance output maps are different from simply measured point value interpolations, rather they have resulted after optimal global model parameters are set through the calibration process. Hence, one of the objectives of the paper is evaluating the hydrological model, and thus giving suggestions for recharge methods to be better applied for different aquifers lying at different topographical settings: this has been clearly put in the discussion and conclusion section of this manuscript. The paper put concluding remarks, where physical hydrological models, would be effectively applied. Why they are less effective for some aquifers and more for others. This helps to take into account the accuracy of recharge values in the area-specific water management plans and decisions being made at different levels.

The next aim of this manuscript is to produce a spatially distributed groundwater recharge rate map for the Lake Tana basin, which is the source of the transboundary Blue Nile River basin where a high tension of hydropolitics is currently affecting the entire region. The spatially distributed recharge rate map produced in this study for the Lake Tana basin is an important output for further groundwater modeling, and water management issues of the basin.

The other one is identifying the most important hydrometeorological and physical factors and prioritizing them for groundwater recharge distribution (qualitatively) for the study basin, and so for similar study areas, including the effect of land use change on the recharge and other hydrological terms. These have been discussed in the result and discussion section and concluded in the conclusion part.

With due you respect, these objectives, especially the first one are important for the international readers. Many hydrological models for different areas (small catchment-scale to large basins) are developed for estimating groundwater recharge. However, evaluation of the method with point estimations based on direct water level measurement (WTF) and chemical tracer (CMB) gives a good insight for future recharge estimation techniques for similar aquifer types wherever they are located in the world. In this study, identifying topographical and geological characteristics, and thus the recharge mechanisms have found an important factor and starting point in selecting recharge estimation methods. The study also pointed out that the common approach that is being implemented i.e. calculating recharge by a multitude of methods and averaging out the results of the different methods is found unreliable. Rather selecting appropriate one or few technique/(s) and considering that as the optimal result is recommended.

Evaluating the groundwater recharge estimation mechanism for the volcanic aquifers lying at different topographical settings, that represents a vast major part of the world groundwater aquifers, and able to suggest more appropriate method/(s) will benefit different further similar studies and researchers. Hence, this study can be seen as a dual purpose paper: evaluating the physical-based hydrological model (and so other similar models), and giving a spatial recharge rate map for the important Lake Tana basin.

Thank you (the reviewer) for your valuable comments, in the new version, shortcomings in the introduction section have been improved as per the suggestions. The research questions are outlined and the contribution of the research output is mentioned in the new version.

The reason why we talk about “choosing appropriate methods” is to direct our reader that evaluation of a method will be one of the objectives of this manuscript. The reason why different methods were developed for recharge estimation rather than using the simplest and cost-effective method is due to the fact that different aquifers have different recharge mechanisms for which some methods are more effective than others. It is why we did evaluation and validation of the existing method. Furthermore, when we say point recharge estimation, we are referring to recharge estimation techniques that estimate at a given point (e.g. on groundwater well, spring, etc.) such as WTF and CMB methods. Otherwise, yes indeed, we agree with the advance of Remote sensing and GIS, and with the developing capability of the grid-based spatially simulating hydrological models, producing spatially distributed water balance maps is so possible and being widely applied. The applied WetSpass model for this study is one of such kinds, and we only applied an existing model (nothing new is done in this study as far as new methodology is concerned). As we have aforementioned, we pursued this study, for evaluating the physically-based hydrological models for our study basin so that areas having similar hydrogeological characteristics will take into account the suggestions of our evaluation result for future application. Besides, the recharge rate map for the basin, which is an important research product for groundwater exploitation practices and plans, will help

groundwater managers and policymakers in this important area which is regarded as one of the growth corridors of the country. Besides, the recharge map is also an important input for further groundwater modeling work.

With due respect, the studies by (Alemayehu and Kebede, 2011; Ayenew et al., 2008; Demlie et al., 2008, 2007b; Kebede et al., 2005) are not all about recharge estimations studies. It is only Demlie et al., 2008, who did a recharge estimation only using the CMB method on a volcanic aquifer for the Akaki catchment located at about 550 km from the Lake Tana basin. The others had made different hydrogeological studies but had put general statements about the recharge variability across the volcanic aquifers. Thus, we can make clear that the presented study in this paper is different from the studies made by these authors.

Some maps in the methodology are shifted to result section as suggested. The shortened explanation of the methodology section is for the reason of shorting the paper. We thought citing the papers that develop the original methodologies and latter modifications will be enough and give detailed background knowledge including the different mathematical equations. However, parameter value modifications that have been done in this paper are discussed and justified in the new version of this paper.