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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Estimation of water yield in the hydrographic basins of southern Ecuador" *by* Saula Minga-León et al.

Saula Minga-León et al.

magomeza@uaemex.mx

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Dear reviewer: We are thankful for the time taken to review our manuscript, and we consider that the questions and comments are appropriate. These have contributed to substantially improving our work, and we hope to make the necessary changes.

General comment: Estimating water yields in poorly gauged areas with large topographical and climate heterogeneity remains challenging. Therefore, the combination of multiple data sources and the use of the model to solve the water budget in areas like the south of Ecuador is very interesting. However, the manuscript is more focused on the specific case than in the broader implications of the proposed methods. This is evidenced in the lack of clear research questions that could go beyond the current

objective: "to estimate and map annual water yield for the 1970-2015 period in nine hydrographic basins of the south of Ecuador". By stating the research questions the conclusions could also be stronger and more relevant to a broader public. Furthermore, you have a large data set (1970-2015) why not use part of it to calibrate the model and the other to validate?

Response: It is important to mention that the annual water yield model is designed for modeling averages in the long term and not in the short term or annually. Therefore, annual precipitation and reference evapotranspiration (ET0) should represent averages over the long term, preferably over at least 10 years according to the recommendations of Sharp et al. (2018). However, to calibrate and validate the model, hydrometric data (water flow) are necessary. For our study, the extent of the water flow data only allowed us to calibrate the model based on the Z parameter, an empirical constant that captures the effects of plant cover, climate, and topography.

Specific comments

1) Comment: Pg3L2: "However, the uncertainty introduced by errors in climate data can be significant and non-spatially heterogeneous, subsequently affecting the estimated spatial distribution of water yield." How will this be considered? does it need to be considered?

Response: The above mentioned question is important. In our study, to minimize uncertainty as a result of errors in climate data, a data quality analysis was carried out. Atypical values were detected, which were subsequently validated, corrected, or eliminated according to various criteria (Pg8L11). Summary of data detected as atypical:

Precipitation: Eliminated 17, Validated 23 and Corrected 2. Maximum temperature: Validated 2. Total data analyzed 44.

However, this study did not specifically focus on an analysis of uncertainty as a result of errors in climate data. Previous studies such as those of Hamel and Guswa (2015), Redhead et al. (2016), and Sánchez-Canales et al. (2012) were also considered. These studies identified uncertainty stemming from variability in climate data and the empirical variables in the corresponding models. Their results show a high sensitivity to precipitation and, to a lesser extent, to evapotranspiration data. The study of Pessacg et al. (2015) showed that errors in precipitation of ±30% led to errors in water yield of 50% to 150% (−45% to −60%) in some sub-basins. Meanwhile, the sensitivity of the empirical variable of the model (parameter Z) is specific to each basin since its effect on yield is modulated by precipitation and available water content (AWC) for plants.

2) Comment: Pg3L8 in relation to pg2L5. Water yields estimated for the 1970-2015 time period are not necessarily "current" given the fast changes caused by land cover and climate change. This also raises the question of how much hydrological variability was observed within this long time period? Could any trends be found? This could be outside the scope of your paper; however, I believe it is necessary to describe the observed behavior of the hydro-climatic variables within the study period as context information.

Response: We agree, it is not necessarily the current water yield considering the land use/cover (LUC) map. The climate variables represent the annual averages for the 1970–2015 period, whereas the LUC characteristics are representative of the analyzed period. The most recent LUC map for the study period (2013–2014) was used. In this study, it would be difficult to obtain hydrological variability in the short term, mostly because of the lack of information in the region in regard to the physical characteristics of soil cover as well as observed water flow data. In this sense, changes were made in the manuscript to clarify these concepts concerning the temporality of data. 1. A clarification was included in the introduction (Pg3L13) that water yield is estimated considering the LUC map of the 2013–2014 period. Also, the word "current" was eliminated at Pg2L5. 2. Figure 2 was included (Pg5) to show the tendencies over time in the hydroclimatic data of the hydrographic basins.

3) Comment: Pg3L11: Are you sure the precipitation range over the Amazon side of the Andes is that low? Please see precipitation data for the cerro El Consuelo (> 4000 mm) Bendix, J., Rollenbeck, R., Fabian, P., Emck, P., Richter, M., Beck, E., 2008. Climate Variability: temporal heterogeneities, In: Beck, E., Bendix, J., Kottke, I., Makeschin, F., Mosandl, R. (Eds.), Gradients in a Tropical Mountain Ecosystem of Ecuador, Ecological Studies.Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 281–290. doi:10.1007/978-3-540- 73526-7 Why not include the data from El Consuelo, if it is available?

Response: Surface precipitation in this study was based on the average values for the 1970–2015 period. Stations located in the Cerro El Consuelo were used in addition to precipitation data from a total of 160 meteorological stations distributed across the study area. Of these, 115 stations belong to the National Meteorology and Hydrology Institute of Ecuador (Instituto Nacional de Meteorología e Hidrología de Ecuador [INAMHI]), 32 to the National Meteorology and Hydrology Service of Peru (Servicio Nacional de Meteorología e Hidrología de Perú [SENAMHI]), and 13 to the San Francisco Scientific Station (Estación Científica San Francisco [ECSF]). The stations of the ECSF are generally located above 2000 masl and distributed across Cerro El Consuelo, Cajanuma, El Tiro, and Tapichachalaca, among other sites. However, the data from these stations are relatively short (from no more than 5 years ago).

4) Comment: pg7L9: You are using a land use map of 2014, which is at the end of the study period (1970-2015). It is reasonable to assume that significant land-cover change has taken place during the study period. How can you assume that a 2014 map is representative for the study period? If this assumption is not supported, how can it affect your results?

Response: Changes in land use/cover (LUC) during the study period could modify the results because of the influence of the physical characteristics of plants. However, the results of this study are valid for the average climate variables (1970–2015) considering the official LUC map of Ecuador for the 2013–2014 period. In future studies, it is important to generate more precise data on variability in water yield with respect to different LUCs if enough temporal data on observed water flows can be obtained.

5) Comment: pg7L16: You estimated PAWC from data available from HWSD? or you obtained PAWC data from HWSD? if the first, please state how.

Response: We appreciate the comment, there was some confusion in the explanation, which was corrected on Pg9L13. The AWC values (mm) were obtained from the HWSD database, and these values were divided by the minimum value of the root restriction depth or rooting depth of vegetation (mm) with the goal of obtaining the required fraction (PAWC) by the Water Yield model. The PAWC values are dimensionless (0 to 1) and are basically obtained by solving equation 5 in the document.

PAWC=AWC/(Min (Rest.layer.depth,root.depth))

6) Comment: pg8L8: Sorry, I do not understand what do you mean by "The calibration was performed up to the elevation of the stations".

Response: Thank you, the phrase was eliminated for not being clear after confirming that the idea was already mentioned in the previous paragraph, which refers to the performance of the calibration of parameter Z by hydrographic unit up to the location of the hydrometric stations and not at the outlet of each hydrographic unit.

7) Comment: pg10L4 and Table 4: Your study area has a very sharp precipitation gradients according to the position within the Andean system (e.g. Amazonian, High-Andean valleys, Pacific slopes). It can be easily predicted that the basins in the high Andean valleys will have a lower water yield and that the ones from the Amazonian side will have a larger water yield by just using precipitation data. In this regard, your aim could go beyond stating which basins have higher water yields and maybe focus more on the limitations to estimate water yields and the importance of understanding how other variables different to precipitation modulate them. Can you please provide information on the position within the Andean system of each studied basin. This information can be provided by an underlying position classification in figure 3f.

Response: Correct, it is known that the climate variables (precipitation and evapotranspiration) modulate the availability of water yield (Hamel and Guswa, 2015; Pessacg et al., 2015; Sánchez-Canales et al., 2012). For this reason, in this study, the calibration of the Z parameter was the focus. This parameter considers soil physical characteristics and plant cover in the study area, which are directly related with the ω parameter. With respect to the comment on Figure 3f, we decided to modify the map of the study area in order to show the influence of the Andean system on the hydrographic basins but did not modify the suggested figure given that it only refers to the model inputs.

8) Comment: pg13Figure6: This is part of your results and they could be better placed in the results section. Also, I do not see how the plot shows what you are trying to explain in L9-10 because in the plot you cannot see anything related to water yield. This plot can be improved. For example, the colors representing the basins could be graduated from higher to lower water yield.

Response: Thank you, we decided to locate the calibration graph of the Z parameter in the Results section.

9) Comment: pg14L24: It is not a matter of algorithms, it is a problem of the available data. If the gauging density does not represent the spatial heterogeneity of rainfall there is no algorithm that can fix it. Once we have data to represent the spatial variability then we can evaluate the best way to interpolate it.

Response: Correct, it is for this reason that a reference (Pg17L23) is made to the lack of available climate data, which is the main problem in the estimation of water yield. In this study, an effort was made to compile the greatest quantity of available data in the study area for the 1970–2015 period. The utilized interpolation method was thin-plate smoothing (Hutchinson, 2006).

Technical corrections:

Pg8L4: An image is not the same as a map. I think you are referring to precipitation and temperature distribution maps. Corrected, the word “images” was corrected and replaced with “maps.” pg10L10 Where are you getting these values from? include reference to Table 5. Corrected. pg11 and Table5: Please correct the units Mm3. A note was added at the foot of the table to explain the units (pg13). pg14L12: I could not find in Table 5 any reference to LUC. A brief explanation was added on pg17L3 about the influence of LUCs on variation in water yield.

Note. The corrected manuscript is attached as a supplement.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-529/hess-2018-529-AC1-supplement.pdf

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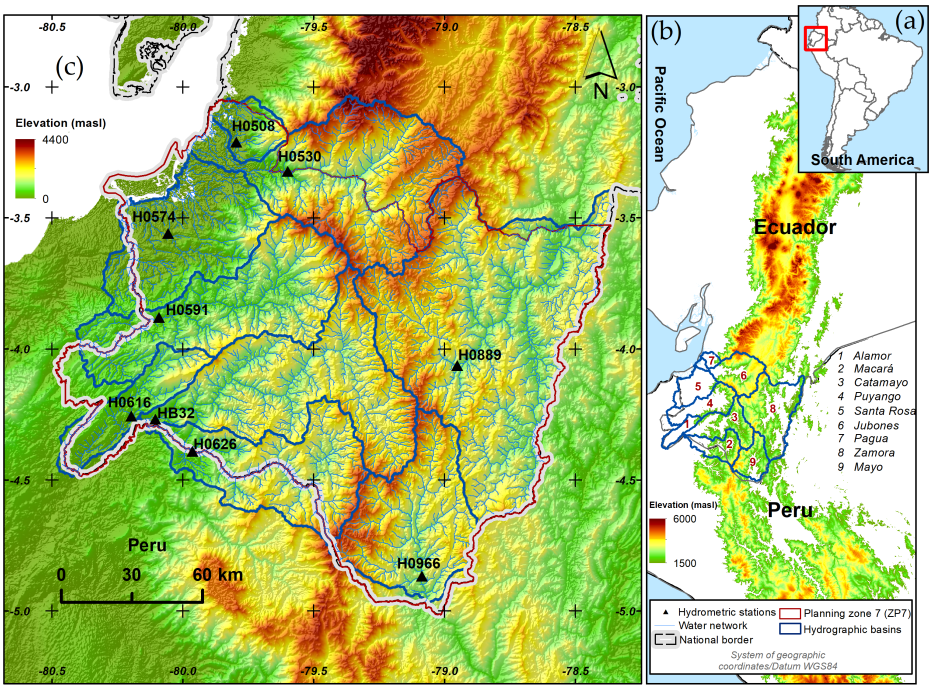

Fig. 1. Location of the study area

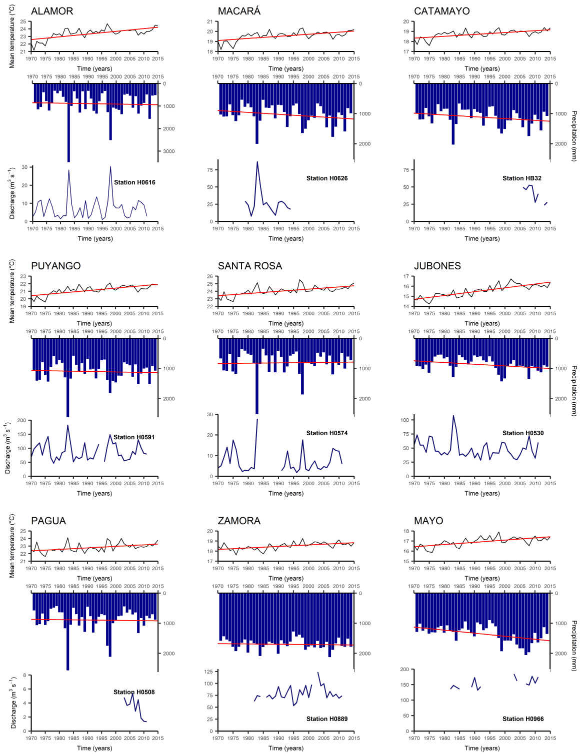

Fig. 2. Hydroclimatic variables