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## Reply on RC1

Judith Uwihirwe et al.

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Author comment on "Integration of observed and model-derived groundwater levels in landslide threshold models in Rwanda" by Judith Uwihirwe et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-222-AC1>, 2021

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Dear Prof. Valentino,

We thank you for the detailed comments and constructive feedback. Please find replies to your comments below:

1) On page 7, rows 184-186, the Authors state that "the extrapolation was undertaken by keeping the parameters constant in each of the three catchments and by implicitly relying on the main assumption here that the subsurface characteristics do not exhibit spatial variability within the individual catchment." This basic hypothesis appears rather strong and oversimplified, as it seems not to take into account the morphology of the area under study and the high variability of altitude and slope. It is believed that the extreme orographic variability of the area can have a significant influence on the estimation of the groundwater level. The model adopted has the merit of being simplified, but in this territorial context there is a risk of making completely misleading estimates. Moreover, taking the same data from a single groundwater station and extending this data not only to the sites of the 3 rain stations (for each sector) but to the whole sector seems rather risky

**Response:** We agree that using the same data from a single groundwater station and extending this data to the sites of the three rain stations and to the locations of landslides in the entire catchment through modelling approaches is risky. However, as you also mentioned, this study was conducted in a data scarce region with very sparse groundwater monitoring wells and ground-based rain stations. We therefore understand the adopted data driven approach as a step forward in data scarce areas that can however be further improved depending on future availability of data with fine spatial resolution.

We will paraphrase the paragraph in lines 184-186 for more clarification. In fact, we did consider the spatial variability of groundwater levels as affected by changes in rainfall and evaporation (model inputs) recorded at each of the 3 rain stations while assuming other parameters to be constant within each individual catchment. However, we are aware that the fine spatial resolution of the groundwater monitoring wells and the rain stations would have led to more improved results in the context of high orographic and morphologic variability territory like Rwanda. We will add a detailed discussion of these limitations in section 4.6 and we hope to find solutions and improvements through our further research in the same area.

2) The second concern deals with the types of landslides considered. On page 7, row 200, the Authors declare that they use a catalogue that includes "42 accurately dated landslides located within the studied region". However, the main characteristics of these 42 landslides are not reported and not explained. The study area is intensely affected by several types of landslides: rainfall-induced landslides, deep seated landslides and also rock falls. In addition, in this area landslides occur very often on steep road cut-slopes, where the influence of the water table as a predisposing or triggering cause remains to be proven. Authors are invited to incorporate some comments related to these shortcomings.

**Response:** As mentioned on page 20, line 483-485, the landslide inventory used for this study relied largely on the information from government technical reports, newspapers, and other media where the accurate information about landslide characteristics such sizes and types is unfortunately not clearly reported. Currently, this landslide inventory is the most available with the highest temporal accuracy (landslide occurrence day) in the study area. However, based on literature and field observations, the general information about landslide characteristics (size and type) that prevail in the study area will be added in section 3. In addition, we will provide a detailed discussion of the potential effects of this limitation.

## TECHNICAL CORRECTIONS

**Comment:** Page 10, row 281: "Ruhengeri" instead of "Ruhengeli".

**Response:** Corrected accordingly

**Comment:** Section 4.2 and Figure 4: the correlation between landslide triggering and increase of groundwater level is not so evident.

**Response:** The Section 4.2 and Figure 4 intend to show that landslides are likely to occur when groundwater level increases at a certain level above the long-term mean as a results of the rainfall received in the past despite some few exceptional landslides that may have been probably induced exclusively by rainfall. In our opinion, the correlation (strong linear correlation) between landslide triggering conditions (here rainfall) and increase in groundwater levels is not supposed to be evident due the time lag between groundwater response and rainfall as affected by the time memory of each catchment. This is also linked to the hydro-geotechnical properties of soil like hydraulic conductivity, permeability and soil texture that contribute to subsequent interplay between infiltration, evaporation and drainage and thus the change in groundwater levels.

**Comment:** Figure 5: the caption refers to square shaped markers for TSS and cycle shaped marker for Rad, but cycle shaped markers are only reported in Figure 5.c: is it correct or some markers are missing?

**Response:** The markers on Figure 5 are correct. We preferred to keep only the square shaped marker (TSS) on the curve once both true skill statistic TSS and Radial distance Rad reveal similar threshold values (See Table 1). Once different both square (TSS) and cycle (Rad) markers are shown on the curve. We will add this information to the Figure caption for better clarification.

**Comment:** Page 20, row 473: "...but the result was not as significant as..." instead of "...but the results was not as significant as...".

**Response:** Corrected accordingly