Response to Referee's Comments from Dr. Jorge Ramirez on

"Towards risk-based flood management in highly productive paddy rice cultivation – concept development and application to the Mekong Delta"

by Nguyen Van Khanh Triet, Nguyen Viet Dung, Bruno Merz and Heiko Apel

General comments:

This paper applies flood modelling to the Mekong delta to determine loses to rice crops. This study builds upon previous modelling studies and methods to estimate damage are adopted from other studies. Overall, the paper is well written and the analysis is good. A major shortcoming of the study is the poor performance of the flood and damage model, and the authors should take care to address the comments related to this topic. I look forward to seeing the revised version of this manuscript.

Authors' reponse: We would like to thank the reviewer for the positive comments and suggestions towards improving our manuscript. We found all comments very useful to enhance our paper quality and clarity. Please find our answers to all raised comments below.

Referee's comment 1: *Line 18: replace "Therefor' with "Therefore".*

Authors' reponse: We will replace in the revised manuscript.

"Particularly, flood risk to paddy rice cultivation, the most important economic activity in the delta, has not been performed yet. Therefore, the present study was developed to provide the very first in-sight on delta scale flood damages and risks to rice cultivation."

Referee's comment 2: *Figure 2: Fully define WS, SA, and AW crop. I am not sure what these abbreviations mean at this point in the paper.*

Authors' reponse: Thank you for pointing this out. We will replace these abbreviations with full text in the revised manuscript as below.

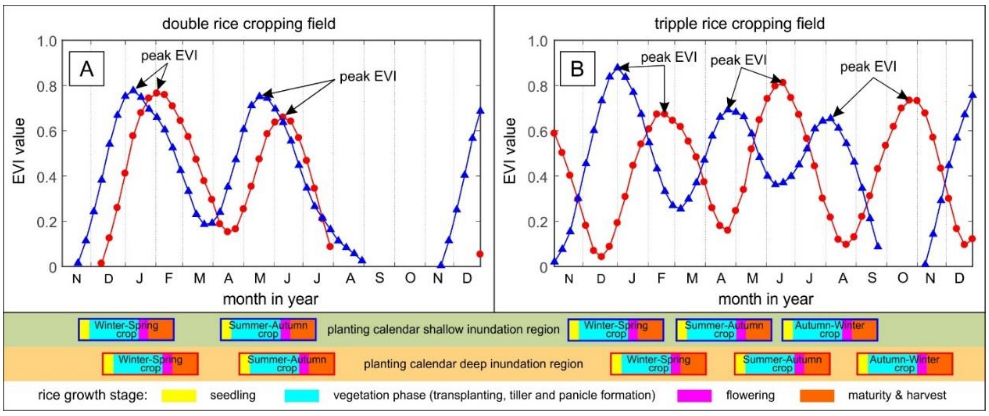

Figure 2. Time-series of the smoothed enhanced vegetation index (EVI) for double (A) and triple (B) rice cropping fields in the Vietnamese Mekong Delta…

Referee's comment 3: *Page 4, line 34: Provide an interpretation for the EVI values (e.g. in general a low EVI means: … and a high EVI means: …).*

Authors' reponse: We will include the following sentence to this paragraph:

There is a shift of 1-1.5 months in the planting calendar between the shallow and deep inundation regions. The Enhanced Vegetation Index (EVI) time-series used to construct this plot were provided by A. Kotera (personal communication, March 01, 2017). An EVI value of 0 indicates no vegetation cover, whereas a value of 1 means complete vegetation cover. The methodology to derive the dataset has been presented in Kotera et al. (2016), and applied to assess economic flood damages to rice crop in the Chao Phraya delta in Thailand from 2000 to 2011.

Referee's comment 4: *Page 5, line 29: Please label station Kratie in a figure and reference this figure here.*

Authors' reponse: We will include the lable for station Kratie in Figure 1 – left panel and add reference to this figure in the correspondence line.

"Synthetic flood events were estimated for station Kratie (Fig.1 – left panel) with 10, 20, 50 and 100…"

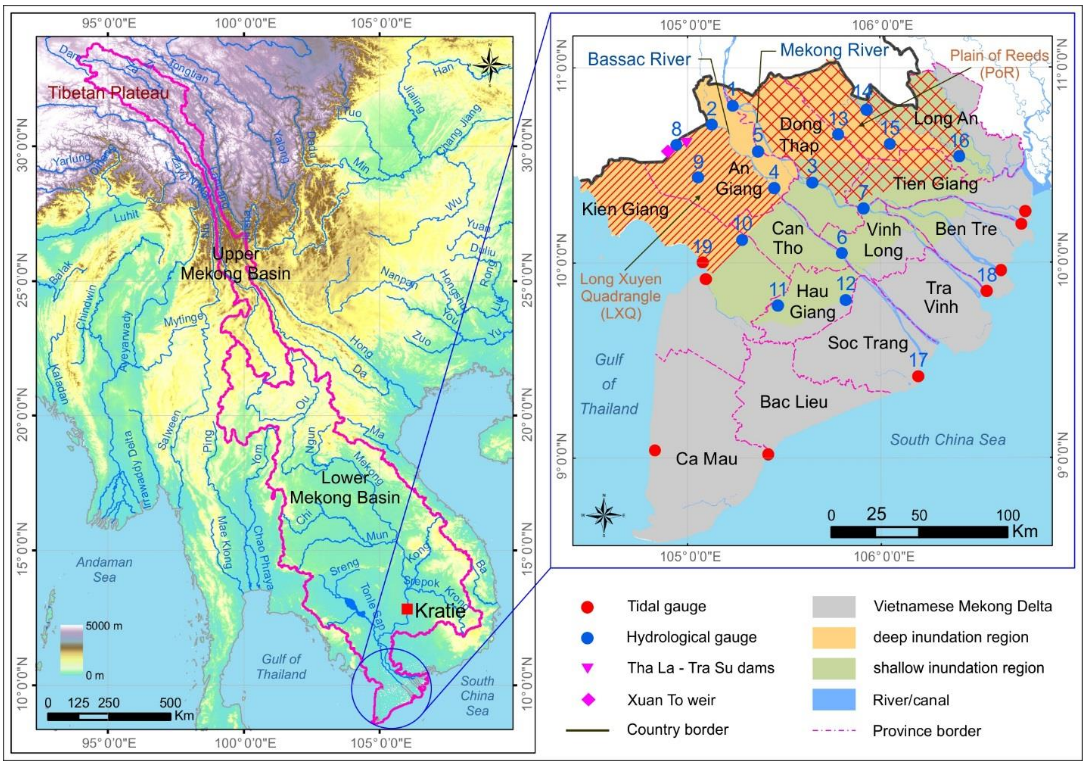

Figure 1. Geographical location of the Mekong Basin (left panel). The Vietnamese Mekong Delta and its flood prone area (right panel)…

Referee's comment 5: *Page 5, line 33: Here you mention a bivariate copula-based statistical model, although you refer the reader to the original study for further details, please provide in your paper a brief summary of this model (2-3 sentences).*

Authors' reponse: Thank you for the comment. We will revise this paragraph as follow:

" Synthetic flood events were estimated for station Kratie (Fig.1 – left panel) with 10, 20, 50 and 100 year return periods, referred to as T10,T20, T50 and T100. This station is commonly defined as the upstream entrance of the MD and is used as upper boundary of the hydraulic inundation model of the MD. The estimation of flood events is based on Dung et al. (2015). The authors developed and tested different bivariate copula-based statistical models on extreme values, using annual maximum discharge Q_{max} and flood volume F_V. Both variables are important for the characterization of the long-lasting annual floods in the MD. From different models being tested, the Gumbel-Hougaard copula was selected as most suitable, with log-normal distributions describing the marginals of Q_{max} and F_V. The outcomes of this study is the very first publication on flood frequency analysis for the MD considering both peak discharge and flood volume. For further details of the bivariate extreme value statistics, we refer readers to the original paper of Dung et al. (2015). "

Referee's comment 6: *Page 6, line 1: You mention that the model has high computational demands. Provide the average wall clock times of your simulations and computer processor specifications to support this.*

Authors' reponse: We will add the following text to support this claim:

"We selected four pairs of peak discharg (Q_{max}) and volume at Kratie (F_V), corresponding to T10,T20, T50 and T100 floods. The most probable pairs were selected from the Q_{max}/F_V pairs with equal joint probabilities corresponding to the return periods specified above. A full probabilistic analysis using a large number of Q_{max}/F_V pairs with equal joint probabilities was not performed due to the high computational demand of the large-scale hydraulic model (on average, 2-3 hours are required for one simulation of the whole flood season June-November on a PC installed with Intel i7-CPU 3.0 GHz, 16 GB RAM). The selected Q_{max} and F_V values range from 56 500 m^3s^{-1} to 66 000 m^3s^{-1} and from 459 km^3 to 525 km^3, respectively"

Referee's comment 7: *Page 7, line 11: Do you mean adopted instead of adapted? If you adapted the stage damage curves, please explain how this was performed.*

Authors' reponse: Thank you for pointing this out. The correct term is "adopted". We will change in the revised manuscript.

" …A_1, A_2 are the total exposed areas classified as partial and fully losses. RD_1, RD_2 are the relative damage factors specified on the basis of the damage curves adopted from Dutta et al. (2003) (see Fig. 4C)."

Referee's comment 8: *Figure 6: No need to have three legends and scale bars if all three images are at the same scale and have the same inundation categories. Reduce to one legend.*

Authors' reponse: We will change in the revised manuscript.

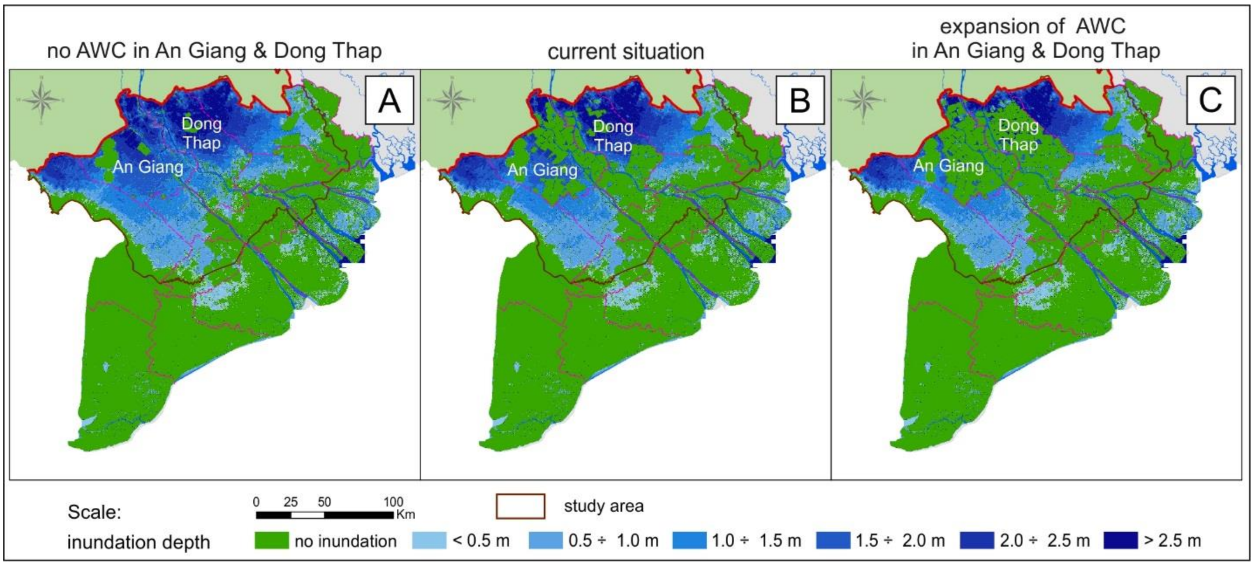

Figure 6. Simulated maximum inundation extent for a 10-year return period flood ($T_{10}shp_1$) for three land-use scenarios…

Referee's comment 9: *Page 8, line 19: Remove "huge" from this sentence.*

Authors' reponse: We will delete this word.

Referee's comment 10: *Page 8, line: Here you report "agricultural damages from the National Steering Committee for Flood and Storm Prevention and Control (US$ 52.8 million)" and compare this to the modelled rice crop loses. Can you clarify if the observed damages only included rice or other crops too? If the later, provide rationale in the text for using this observed damage estimate from various crops to validate your rice damage model.*

Authors' reponse: As mentioned in the text, the observes damages included other agriculture crops and facilites. All these damagees were lumped to a single value. And this is the only information available to validate our damages estimation. We will revise this paragraph to provide the rationale of using the observed damages data.

"We estimated rice crop losses of US$ 42.7 million. This number is equivalent to 81% of the reported 15 agricultural damages from the National Steering Committee for Flood and Storm Prevention and Control (US$ 52.8 million) (MRC, 2011). Flood damages to other agriculture crops and facilities as e.g. farmhouses, which were included in the reported damages (lumped to a single value categorized as agriculture losses), were not yet incorporated in the presented damage estimation. Considering that paddy rice is the predomimant crop in the delta, it is very likely to share a large part of the reported losses. Paddy fields derived from the land-use LC2014 raster, account up to 72% of whole agriculture land within the focus area of this study. This amount closely matches the share of paddy rice in the summed agriculture losses at 81%. Being acknowledged that spatial distribution and market prices of different crops might play certain role, arguably our results are likely to map the actual flood damages to rice cropping. In general, although not being the ideal piece of information, the reported agriculture losses were the only available data to evaluate our rice crop damages calculation."

Referee's comment 11: *Page 8, line 21: Define the flood areas index. Also, what is an acceptable FAI, and a poor FAI? Please provide this information in the text.*

Authors' reponse: We would like to thank the reviewer for poitning out that the flood areas index is not defined in our manuscript. We will revise the correspondence paragraph to provide this information.

A large share of the overestimated exposed area of rice crops can be attributed to the simulated inundation extents, although ~~huge~~ efforts have been made in updating, refining, and calibrating the model (Dung et al., 2011;Manh et al., 20 2014;Triet et al., 2017). The main source of uncertainty stems from the interpolation of 1D model results to a 2D raster, which could not be reduced even by the high resolution LiDAR DEM. Triet et al. (2017) reported a flood areas index (FAI), of 0.64 for the comparison of modelled and observed inundated areas for the whole VMD. The FAI was computed by deviding the sets of pixels presenting the intersect of observed and simulated inundation with the set of pixels preseting the union of observed and simulated (Eq. 3 in Aronica et al. (2002)). This value increased to 0.74 if only the flood-prone area of the VMD was considered. According to Aronica et al (2002), who suggested that a FAI higher than 0.7 is considered as acceptable for an inundation simulation model, it can be concluded that the performance of the inundation model for the VMD is acceptable for the flood prone are of the VMD, where the bulk of flood damages occur.

Referee's comment 12: *Page 8, lines 33-36: Delete these lines, the comparison between modelled and observed inundations and losses somewhat refutes this. You could state this if the model had a better FAI and the model replicated multiple observations (e.g. various flood events) of rice losses.*

Authors' reponse: Please find our clarification on the performance of the damages model in the response for comment No. 13 below. Therefore, we think that we can keep these lines in our manuscript.

"Despite these deficiencies, the flood damage assessment proposed in this study can produce reliable results, particularly when the typically 35 large errors in flood damage estimation are taken as reference (e.g. Schröter et al., 2014). Thus the proposed method is judged to be appropriate to estimate flood hazard and risk to rice cropping in the VMD."

Referee's comment 13: *Page 10, lines 7-12: Why is there a 73% difference between the modelled worst case scenario damages (T100) and observed damages from a 20-year flood? Doesn't it mean that the model is severely underestimating damage? Please explain this difference in the text.*

Authors' reponse: The comment regarding damages differences between the worst case 100-yr event and the flood event in 2000 (20-yr), might be a misunderstading generated by the authors. We did not mean to directly compared damages between these two events.We actually aimed to illustrate the importance of the flood control structures being constructed in the delta after the historical flood in 2000, which is estimated as a 20-year flood mentioned in the next two sentences in the same paragraph. After this disastrous flood, the government of Vietnam promoted the delta flood management programme. It resulted in construction of thousands of kilometer of man-made canals, together with dykes and flood control structures e.g. sluice gates, and weirs. In our damages estimation for the worst case scenario (the 100-yr event), those dyke lines and sluice gates (up to the year of 2011) were included in the flood model. Therefore, the damages were substantially reduced, compared to the system in 2000 where many of the flood control strucures were not in place. We clarify this paragraph as:

"Our worst scenario, i.e. $T_{100}shp_3$, resulted in damages of US$ 115.7 million. This value is less than half of the reported damages of the flood in 2000 (US$ 250 million; reported by (MRC, 2012)), which is considered as a 20-year flood (Le et al., 2007). This huge reduction in losses can be directly linked to effective flood management and adaptation measures being implemented in the VMD following the "Decision No. 99/1996" on flood control and development plan for the delta from the Government of Vietnam (The Government of Viet Nam, 1996)." Note that the plan was initiated in 1996, but was implemented to a large extend after the flood in 2000 occurred.

Referee's comment 14: *Page 11, lines 37-40: Here you state that a 2D modelling approach would require the implementation of detailed man-made structures and this hinders the adoption of a 2D approach. Can you explain in the text how in contrast your 1D approach easily represented man-made structures?*

Authors' reponse: In the VMD over 85 000 km of canals/rivers, 14 000 km of dyke-line, about 1000 sluice gates of 3-100m width, and over 10 000 more with width less than 3 meter exist (Hung et al., 2014). These structures heavily regulate the flood regime in the delta. To captures the dynamics of delta inundation, a fully 2D approach should have a spatial resolution at 5x5 at minimum to represent dyke-lines (with the width at crest generally less than 5 m) properly. Thee dyke lines need to be implemented to the underlying DEM with correct elevations. This means that any DEM needs to be checked if dyke lines are present in the grid, and if they show the correct elevation. If not, this needs to be corrected, which is time consuming.

In our quasi-2D model these dyke-lines are presented as broad-crest weirs in the model structure at the simulation nodes only (the concept is demonstrated in Fig.5A). Thus the implementation of hydraulic structures is less cumbersone in this model structure compared to a fully 2D model.

However, the main restriction of using a fully 2D model in a risk assessment are the runtimes of these models. The huge area covering more than 4 million hectare is still a large challenge for 2D models at high resolution, even with the now available computational facilities.

Reference

Aronica, G., Bates, P., and Horritt, M.: Assessing the uncertainty in distributed model predictions using observed binary pattern information within GLUE, Hydrological Processes, 16, 2001-2016, 2002.

Hung, N. N., Delgado, J. M., Güntner, A., Merz, B., Bárdossy, A., and Apel, H.: Sedimentation in the floodplains of the Mekong Delta, Vietnam. Part I: suspended sediment dynamics, Hydrological Processes, 28, 3132-3144, 10.1002/hyp.9856, 2014.