Dear reviewers,

We sincerely thank the reviewers for their feedback and evaluation of our manuscript. Their comments and suggestions were highly valuable and helped us strengthen the overall quality and presentation of the study.

The revisions include improvements to the organisation and flow of the manuscript, as well as additional clarifications regarding methodological framework, validation approaches, interpretation of results, discussions points, and limitations. We have addressed all comments raised by the reviewers and indicated the corresponding changes in the revised version of the manuscript.

Detailed responses to each reviewer comment are provided below. Responses are presented below in *blue italics* and are prefixed with "R:".

Reviewer 1 Comments (RC1)

This is a nice paper attempting to merge economic losses from floods using standardised approaches to loss modelling with health impacts due to Rotavirus and E. Coli. The model is built and tested in Can Tho city in Vietnam. Please see my comments and suggestions below.

<u>Major:</u>

I don't think it's clear what exactly you are modelling in section 2.2.1. Your input data is the observed losses in the 2011 floods. But I'm not sure what is coming out the model/what the objective of the modelling is. Can you provide more clarity please? Similarly for the pathogen models in 2.2.2 where the input data is measured pathogens in the 2016 floods. In general, you have a lot of similar looking equations and it's not always clear what the differences are. On this note Figures 2 and 3 don't provide that much extra clarity. Could these be updated to better represent the modelling approaches?

R1: Thank you. We agree that the modelling objective was not sufficiently explicit in Section 2.2.1. To improve readability, we will revise the methods section and present each model in a more transparent bullet-point format, clarifying for each model: (i) the input data, ii) model characteristics and (iii) the model output. In the cases of both flood loss model and pathogen concentration models, we use empirical data and probabilistic regression models to determine relationships of the outcomes to drivers. These relationships are then applied to the flood-hazard simulations for risk assessment.

Flood loss model:

- *Input data: observed residential building losses from the 2011 flood survey (see Chinh et al., 2015 for further details), together with flood intensity such as water depth (wd) and building characteristics such as the building value (bv) (Apel et al, 2016; Oostwegel et al., 2025).*
- *Model characteristics: Bayesian Regression models with zero-one inflated beta response distribution.*
- *Model output: Posterior predictive distribution of relative building loss (rbloss) which is conditioned on the flood characteristics and building attributes as predictors.*

Pathogen concentration models:

- *Input data: measured pathogen concentrations from the 2016 flood samples (see Hyun et al., 2024).*
- *Model characteristics: Bayesian Regression models with hurdle log-normal response distribution.*
- *Model output: Posterior predictive distribution of rotavirus A and E. coli concentrations in floodwaters.*

The pathogen concentrations are then propagated through the QMRA pipeline to estimate infection probability and illness probability. The objective is to infer a concentration model that can be applied across the hazard layers, not merely to fit the sampled points.

Section 2.2.2 already states the model inputs and outputs clearly. Therefore, only section 2.2.1 is subsequently revised by adding the following after introducing the input data:

- *"The data were used to calibrate a probabilistic flood loss model for residential buildings.".*

We also agree that the equations can be made more readable by explicitly stating what varies and what is being compared.

- *In Section 2.2.1, the equation set defines a zero-one inflated beta regression for bounded relative loss data, with predictors influencing the mean (μ), while inflation and precision parameters are kept constant.*
- *In Section 2.2.2, the candidate pathogen models are compared. We compare an intercept-only negative binomial formulation with a hurdle lognormal formulation, and then optionally include additional predictors components (i.e., topographic slope – topo, diameter of the closest sewer – sewer, inverse distance to the closest sewer – inv_d, and water deptj – wd).*

We agree that Figures 2 and 3 could better distinguish the modelling logic. Figure 2 should more clearly show that the building-loss model takes empirical 2011 loss observations as calibration input and produces a predictive loss distribution that is later coupled to hazard maps and building exposure. Figure 3 should likewise indicate that the 2016 pathogen measurements are used to calibrate a concentration model that feeds the QMRA chain, rather than serving as a direct end product. We will therefore revise both figures to include: 1) input variables, including clear "calibration" labels for the empirical datasets, 2) modelling type and main tasks, and 3) outputs. Additionally, a final arrow showing how the output is propagated into the downstream risk metrics.

It's great that you differentiated your building structures by use type (residential, commercial, and industrial structures) but the expected structural loss of a building also depends on the type of construction material (wood, concrete, steel etc.). How do you account for this in your loss modelling?

R2: Construction implicitly material is accounted for in our loss modelling through the building value variable, that originate from the survey data. Building value is calculated as the product of floor area and a price per square metre defined according to building material type (e.g., wooden, tiled, concrete) by the Can Tho City People's Committee (Chinh et al., 2016). For further details on the building value and the survey, please refer to Chinh et al. (2016).

It would be good to see maps of the inputs/intermediate stages of your models. For example, sampling locations for the 2011/2016 datasets. The various exposure models, the inputs and interpolated results of the "time of exposure" maps etc. We only really see maps of the final results from Figure 5.

R3: These maps are now included in the Supplementary Section S.3 "Exposure and QMRA Model Outputs", including the interpolated results for the time of exposure (t_e), and the exposed population to flooding, in addition to the intake dose (μ), the probability of infection (P_{inf}) and illness (P_{ill}).

Given that you test multiple different models for the losses, it would be good to have more in the discussion around the relatively strengths, accuracies of these. Currently you just state in Line 334 that m2 was the best without giving the quantitative justification for this assessment.

R4: We agree that the model selection should be justified more explicitly. In the revised manuscript, we expand the discussion of the candidate loss models and report the quantitative criteria used to evaluate them, including their comparative fit and predictive performance by mainly referring to the Supplementary Materials S2 (Bayesian Regression Models). Based on these metrics, m2 showed the best overall performance and was therefore selected for the final analysis, stating clearly that the selection was based on ELPD, referring to the Supplementary Materials for the full model comparison. We also clarify why the other specifications were less suitable, for example due to weaker fit, poorer predictive performance, or less stable parameter estimates.

I'm not sure if your *coli* model has worked correctly. Your lower bound and median is (0 Figure 8). Can you show evidence (ideally graphical) how well your model captures the measured cases used to build/calibrate the model?

R5: The lower bound and median of the E. coli predictions (ecoli model) are zero because the fitted model is a zero-inflated/hurdle model and the observed pathogen measurements include a substantial number of zero values. This is reflected in the posterior predictive distribution, where the central tendency can therefore be at zero even when the model still captures the non-zero tail well. To demonstrate model performance more clearly, we will edit Figures S1.1 (Data description in Supplementary Material), a graphical comparison between the observed calibration data and the model predictions by showing the empirical distribution of measured E. coli concentrations alongside the fitted posterior predictive distribution, and by including in the density plots observed-versus-predicted curves, clearly identified with a legend.

Given that the median EAC for *coli* is zero, I don't understand how you have E. Coli losses in Figure 9b. I would also urge you to check the bivariate map for EAD/EAC – Rotavirus too. From the individual EAD and EAC it seems the numbers are inaccurate, e.g., PTU here is in the $3,566k-$4,724k category when it's median value in Figure 5 is $1,392k.

R6: In Section 3.2, the median EAC for E. coli is zero because the distribution is highly right-skewed and contains a substantial mass at zero. Consequently, the map in Figure 9b (section 3.3) is based on the higher quantile (Q_{75}) rather than on the median alone. As a result, locations can still fall into a non-zero E. coli loss class even when the median EAC is zero, because the upper tail of the distribution contributes to the mapped category. We mentioned the reporting of only Q_{75}, for both PHaR and EAC in section 3.2. However, to improve clarity, we added:

- *"EAC attributable to E. coli is non-zero only above the 75th percentile of the distribution. Accordingly, the Q75 estimate of EAC is reported at the ward-level and discussed in this section. This reflects the right-skewed distribution of E. coli cases, in which the median remains zero while the upper tail captures non-zero Estimated Annual Cases.".*

Additionally, we previously clarified this distinction in the text to avoid confusion in the description of the Figure:

- *"Figure 9. Bivariate choropleth map showing flood-related economic and health risks for children under 5 years old as a vulnerable population in Can Tho (Q_{75})".*

Additional clarification is added to the manuscript, in section 3.3:

- *"Figure 9 depicts bivariate distribution maps of the spatial relationship between economic risks and disease burden in Can Tho city, using the 75th percentile (Q75) results obtained for Expected Annual Damage (EAD) and Expected Annual Cases (EAC). We use the upper quantile to emphasise elevated risk plausibility, capturing less frequent yet substantial impacts. The colour gradients represent the intersection of both indicators. Darker tones indicate a higher intensity of the risks, while lighter shades correspond to lower combined risk levels. The highest intersected risks for both pathogens are concentrated in Phu Thu (PTU) and Thuong Thanh (TT) wards of Cai Rang district, as well as An Binh (AB) ward in Ninh Kieu district. Rotavirus A exhibits higher combined risks at the upper bound, whereas E. coli is more weakly coupled to economic losses. Conversely, low-risk areas are consistent across both pathogens, reflecting low economic losses and low disease burden. These are located in the Ninh Kieu district, particularly in the wards of An Hoi (AH), An Lac (AL) and Tan An (TA).".*

We also appreciate the comment on the bivariate EAD/EAC map. We checked the mapping procedure and the individual EAD and EAC estimates. We verified the correctness of our results. The example of PTU suggested that the numbers are inaccurate, referring to the differences using Figure 5 as an example. Figure 5 shows the Value at Risk (VaR) for the residential building losses, whereas the EAC map is displayed in Figure 6. For EAC, PTU shows a value higher than 4,000 k US$ at the upper bound (Q_{75}), value used for the choropleth bivariate map, not the VaR.

<u>Minor:</u>

Abstract: Please can you include more details of your findings in the abstract. The only really finding you mention in there is this sentence "highest combined economic and health risks are found in Phu Thu and Thuong Thanh wards (Cai Rang district) and An Binh ward (Ninh Kieu district), while An Hoi, An Lac, and Tan An wards (Ninh Kieu district) experience consistently low risks", but it doesn't say anything quantitative about what these risks are or what low even means.

R7: We value this suggestion and agree that the Abstract could report quantitative results. We expanded the text to include a summary of the risk indicators, reporting 75th quantile values for EAD and EAC:

"Results at the 75th percentile (Q_{75}) show pronounced spatial disparities in intersecting risks. The highest co-occurring economic and health risks are found in Phu Thu and Thuong Thanh wards (Cai Rang district) and An Binh ward (Ninh Kieu district), with values reaching US$36,624k, 3,858 cases, whereas An Hoi, An Lac, and Tan An wards (Ninh Kieu district) experience consistently low risk (maximum of US$116k, 16 cases). These findings highlight how urbanisation and flooding interact to shape multi-sector vulnerabilities in delta cities."

Introduction: This is too long and much of the basic definition sections can be shortened/removed.

R8: We note that the Introduction is long.

We reduced it by excluding Paragraph 2, regarding the IPCC framework, a well-known and stablished risk framework. We retained the sentence linking the framework to our study context, and joining it to the first paragraph:

- *"Understanding flood risk requires an integrated assessment of dynamic interactions of hazard, vulnerability, and exposure (IPCC, 2012), whose changing patterns are major contributors to increased losses, stressing the importance of understanding the nature of these* *components for the development of effective adaptation and disaster risk management strategies (Climate and Development Knowledge Network, 2012).".*

Paragraph 4 was revised to focus exclusively on residential building losses, removing references to agricultural, industrial and commercial economic losses. This was deliberately shortened to avoid raising expectations on results this study does not address, and is consistent with our response to the second reviewer regarding the exclusion of broader economic activities such as aquaculture.

- *"Economic losses from flood events to assets have widely been studied, with recent research resulting in various models that capture their related losses. These models range from traditional depth–damage functions, which link flood water depth to monetary loss, to more advanced probabilistic and multivariate approaches that incorporate exposure and vulnerability factors (Merz et al., 2010; Jongman et al., 2012). In Southeast Asia (SEA), an area where flooding poses substantial risks, region-specific flood loss models are increasingly being developed. For example, flood depth–damage functions and the incorporation of additional variables (e.g., flood duration and velocity) have been developed to assess losses related to property and household impacts (D'Ayala et al., 2020; Romali & Yusop, 2021). Despite these advances, most applications remain centred on losses related to economic sectors, while the social and health dimensions remain underrepresented in flood loss modelling.".*

Line 35-37: This sentence needs a reference.

R9: We agree that the sentence should be supported by references. We, therefore, include the works of Thompson et al. (2015) and the World Health Organization (WHO, 2022). These references strengthen the framing of the problem by better situating the health impacts of flooding within the existing literature.

Line 53-54:

R: We revised these lines. If the reviewer meant to write that the sentence needs a reference, we do include several references for this.

Figure 1: The right panel shows the flood inundation map. Is this for a particular event? Or is this the expected inundation hazard? Given that you have rp =100 yr I'm assuming it means inundation hazard. Please be clearer with that the figure is showing, perhaps with a more detailed figure caption. When this figure is referenced in the text you also don't explain how the hazard was calculated or where it was sourced from.

R10: We agree that the caption could be clearer. The right panel of Figure 1 shows the probabilistic flood inundation hazard, not a single event. Inundation depth for the 100 yr return period is illustrated in the Figure as an example. These are obtained from the probabilistic fluvial-pluvial hazard inundation maps as described in Apel et al. (2016), referenced also in the Figure. Details on the modelling, return periods, and inputs are provided in Section 2.3.1.

We updated the Figure caption and added in Section 2.3.1. the cross-reference to make these points explicit:

- *"Figure 1. Left: Location of Can Tho in Vietnam. Right: probabilistic flood inundation hazard, water depth, for the 100-year return period (rp = 100 yr), presented as an illustrative example* *(see Section 2.3.1 for details on the hazard simulations). The study area comprises three urban districts of Can Tho: Binh Thuy, Ninh Kieu, and Cai Rang.".*

- *"The inundation simulations for different return periods and the derivation of the associated boundary conditions are based on the probabilistic fluvial-pluvial flood hazard analysis presented in Apel et al. (2016), but extended to cover the three districts of this study (see Figure 1, right).".*

Supplement 1.1: It's not clear to me how the curves were determined. Is this a smoothed fit to the histogram? Please also include in the caption what the dotted line indicates.

R11: Supplement 1.1 – Figure S1.1. shows a kernel density estimates of the relative building loss, rotavirus A and E. coli concentrations distributions rather than smoothed fits to histograms. The dashed line indicates the mean value of the distribution, and the rug marks along the x-axis show the individual observations used to construct the density plot. To avoid ambiguity, we revised the caption to:

- *"**Figure S1.1.** Density estimates of the distribution of survey data: relative building loss (rbloss; %), and concentration of rotavirus A and E. coli (x10^6 gc/mL, x10^3 CFU/mL, respectively). The dashed vertical line indicates the mean, and the rug marks the individual observed values.".*

Equation 2c: I think you are missing a variable in the logit().

R12: The equation was corrupted while formatting. It has been corrected. See Equation 1c:

"$logit(\lambda) = \alpha_\lambda$ (1c)"

Supplement 2.1: I'm afraid I don't understand the equation setup here. What does the rbloss ~ indicate in this and why are these different to equation 3 in the manuscript?

R13: The notation rbloss ~ [...] indicates that relative building loss (rbloss) is the response variable being modelled as a function of the predictors listed after the ~ symbol. In Supplement 2.1, these formulations are not new equations and are distinct from Equations 1 a-d, but represent the model candidate specifications already displayed in Equations 2-4, the structures for the three models: m_1 is the full multivariate candidate model; m_2 is a reduced bivariate model; and, m_3 is the intercept-only model. To avoid ambiguity, we add a sentence in S2.1 before the formulae:

- *"These are candidate model formulations used for model selection, as presented in the model structures of Equations 2-4.".*

Lines 241: How was Apel et al., (2016) extended to cover your three districts and how did you refine the spatial resolution n to 5m? Did you rerun those models?

R14: The flood hazard analysis was based on the probabilistic fluvial-pluvial work presented in Apel et al. (2016), which covered the city of Can Tho. The 5 m resolution refinement was carried out in the same work. We did not rerun the original Apel et al (2016) model chain.

We resampled and clipped these inputs to match spatially the extent of only the three districts included in this study.

Line 298: can you provide the alpha and beta values for the pathogens that you used. Perhaps in Table 1? Also, the unit column in Table 2 is incomplete

R15: The pathogen-specific alpha and beta values, along with other specific parameters used in the QMRA are already reported in Table 1, in Section 2.3.3. Quantitative Microbial Risk Assessment (QMRA).

- *"The risk of illness is a specific parameter of each pathogen. These parameters are given in Table 1:".*

The metrics for the relative building loss (rbloss) model reported in Table 2 are dimensionless, therefore carrying no unit. We indicate in the Table that it is a relative value, ranging from 0-1, corresponding to no loss to total loss.

Line 318: Typo: D(p) instead of Dp.

R16: We thank this comment. The typo was corrected.

Loss results: It's a little confusing how you present your loss results, e.g., US$1,392.25k. This is too precise given the uncertainties in your data. I would recommend you present the results at a lower precision, e.g., US$1,400k.

R17: The results for EAD were changed to reflect a lower precision, adding the units for each value (US$):

- *"The total EAD for Can Tho was estimated at a median of US$10,684k, with an interquartile range (Q_{25}–Q_{75}) of US$610k to US$36,624k. Through the median (Q_{25}; Q_{75}) of EAD, the wards of Phu Thu (PTU), Thuong Thanh (TT), and An Binh (AB) displayed the highest estimated losses, with values of US$1,400k (US$ 82k; US$ 4,700k), US$860k (US$ 50k; US$ 2,900k), and US$670k (US$ 37k; US$2,400k), respectively. These results indicate that Phu Thu ward in Cai Rang experiences high economic losses in the city.".*

Figure 9: I think your EAD and EAC threshold could be cleaner. Consider changing these to lower precision bounds: E.g., EAD: 0-1200; 1200-2400; 2400-3600; 3600-4800. Similarly, for the EAC.

R18: Figure 9 was edited to include lower precision bounds that could inform EAD and EAC results.

Reviewer 2 Comments (RC2)

<u>General comments</u>

Thank you very much for the opportunity to review a paper on Quantifying Compounded Economic Impacts and Disease Burden of Flooding in Can Tho, Vietnam, a topic that is relevant and interesting to the readership of EGUsphere. This manuscript addresses a timely topic and political, as well as societal challenge, and is worthwhile being considered for publication. Yet, major revision, discussion and clarification is needed.

One major concern is that while authors claim they integrate economic and health risk modelling, the models seem to treat both separately. This needs to be improved, or the claim needs to be moderated.

Also, while the study is limited in several ways, limitations are not mentioned at all. Ethics aren't either. Below, a list with suggestions is recommended to authors to consider.

R19: We thank the reviewer for their valuable comments. We acknowledge that the economic and health risk models are calibrated and run independently, each drawing on sector-specific data and methodologies. However, the integration occurs at the risk quantification and spatial analysis stage, where probabilistic outputs from both models are combined within a unified framework to identify wards experiencing co-occurring economic and health burdens simultaneously. To reflect this, we have rephrased the text from "combined risks" to "co-occurring risks".

<u>Specific comments</u>

<u>Introduction/framing</u>

A clear highlight of the novelty of this manuscript is missing, related to content, approach, etc. Can you please highlight the value and novelty more explicitly? Study rationale, aims and objectives are not fully clear, and differ throughout the manuscript. Please make sure you clearly state what is the aim of this work, incl. the target group considered (children below the age of 5 years old).

R20: We agree that the explicit mention of vulnerable population groups in the introductory section, particularly under the study objectives, was necessary and have addressed this accordingly. We have revised the objectives statement to read:

- *"The main objective of this study is to quantify the co-occurrence of economic losses and disease burden to rotavirus A and E. coli in Can Tho. To achieve this, we calibrate two specific models. The first, flood impact models for the economic sector by predicting building losses to the residential buildings. The second, for the health-sector by predicting contamination-levels of pathogens in flood waters and the subsequent consequences on human health. Vulnerable populations are defined, in this study, as social groups including children under 5 years old and seniors older than 65 years old. This multi-sector focus allows for a comprehensive assessment of built-environment and public health vulnerabilities. To this end, we calibrate and validate a state-of-the-art Bayesian Regression Model for flood loss estimation in private households and implement QMRA considering rotavirus A and E. coli contamination in flood waters. We integrate the developed economic and health impact models with probabilistic flood hazard maps with different return periods, and population and building exposure datasets.".*

We have also ensured consistency between these objectives and the framing used throughout the manuscript, including the methods, results, and discussion sections, so that the aims are reflected coherently across the paper. Model results for the two target groups were presented in Table 3 (Section 3.2.2. Flood-related Disease burden), and the focus on children below 5 years old was mentioned before presenting the results for PHaR and EAC.

Regarding the novelty, the explicit integration of probabilistic economic and health risk quantification within a single spatial framework, rather than treating these as separate assessments, constitutes the primary contribution of this work, and we have noted this in the introduction.

While the title prominently suggests to address compounded economic impacts and disease burden of flooding, the links between the two aren't made explicit enough in the introduction.

R21: The linkage between economic impacts and disease burden in the introduction was revised. The revised version emphasises that flooding can generate co-occurring economic and health impacts:

- *"Such quantitative assessments of flood impacts in the economic and health sectors have been conducted separately across spatially and temporally heterogeneous contexts. Flooding can simultaneously damage residential assets and expose populations to contaminated floodwaters. These two impact pathways should be assessed together rather than in isolation. Integrating economic flood loss models with QMRA-based health risk assessments offers a pathway towards comprehensive flood risk assessment and management across economic and health sectors, with a particular focus on co-occurrence of economic and health burdens.".*

The loss and damage literature related to climate change and extreme weather events such as flooding has grown over the past decade, and authors are encouraged to refer to relevant frameworks, e.g., Sendai, here, and more explicitly state what are economic, and also, non-economic losses. This is both very relevant for this paper, and it is advised to contextualise results of this research respectively in the discussion section.

R22: We agree that the growing literature on loss and damage, including frameworks such as the Sendai Framework for Disaster Risk Reduction 2015-2030, provides context for our research. We introduce this in the Introduction section: "Also characterised as direct and indirect losses, direct losses include the loss of human life, damage to infrastructure, and business interruption, while indirect losses are associated with, for example, changes in long-term wellbeing and development. These latter impacts are harder to estimate and, thus, remain usually underreported (UNFCCC, 2012).".

Although a detailed classification and more advanced assessment of economic and non-economic losses is beyond the scope of this research, we acknowledge the relevance of literature. We added discussion to these frameworks and studies to better contextualise the presented results:

- *"Despite these limitations, the study contributes and advances the emerging body of flood-related loss and damage literature. The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015) provides a pertinent reference point, as it explicitly calls for the assessment of both economic and non-economic losses from disasters, as well as for the integration of health risks into disaster risk governance. The economic losses quantified in this study as the Expected Annual Damage (EAD) of residential buildings represent a subset of direct losses, while the disease burden quantified through the Population Health at Risk (PHaR) and Expected Annual Cases (EAC) captures one dimension of non-economic impact related to morbidity from waterborne pathogen exposure. Nevertheless, this study does not entail a comprehensive loss and damage assessment, as it develops and demonstrates a multi-risk framework to jointly quantify spatial and distributional disparities in economic and health flood risks in Can Tho city. Additional economic and non-economic losses beyond EAD and EAC, such as impacts on mental health, livelihood disruption, and impeded access to healthcare services, fall outside of the scope of this analysis and were excluded. Future work integrating these additional dimensions should move towards a full loss and damage assessment.".*

Public health risks resulting from flooding are mentioned frequently, yet, what is missing is a mention, consideration, critical discussion of the effects that flooding have on the accessibility to health services and medication. Exposure to infection is one thing, getting ill – and staying ill, another. Accessibility to care, and flood- "disturbed" health seeking behaviour, even if not analysed in this paper, is a very important factor that cannot be omitted.

R23: We agree that flood-related disruption of health services and impeded care-seeking behaviour are critical factors in translating pathogen exposure into a more advanced diseased burden outcome.

Exposure to infection is one outcome, but whether affected individuals can access timely care determines the severity and duration of the illness (an additional outcome). We acknowledge that this dimension is not capture by our study, which models exposure and infection risk but does not account for downstream healthcare access or care-seeking behaviour. Since this is outside the scope of the current study, we have mentioned it in the limitations and as a potential direction for future work. For instance, the intake rates (IR) are currently parameterised by activity type and age group following Dorevitch et al (2011) and Huynh et al. (2024). This provides a foundation upon which future work could build to incorporate accessibility to health-services, behaviour and awareness as additional dimensions of disease burden.

<u>Methods</u>

Study area description largely lacks contextual information on disease burden overall, economic situation overall (and reliance on aquaculture), flood management in the Vietnamese Mekong Delta, where the Mekong River Commission has been very active to address economic as well as health impacts. Study area description mentions environmental pollution without further specifying, yet, this is very important information in the context of infectious disease exposure.

R24: Overall details on the economic situation of households and disease burden in can Tho are documented in the studies upon which this work builds, namely Chinh et al. (2015, 2016, 2017) and Huynh et al. (2024).

Regarding environmental pollution, since water quality testing was not conducted as part of this study, the contextual information on water contamination is drawn entirely from existing research already cited in the manuscript (i,e., Nguyen et al., 2017; Huynh et al., 2019). We therefore opted not to repeat details already documented in those sources. We already reference to environmental pollution in the study area description to make its relevance to infectious disease exposure more explicit.

- *"In addition to flooding, the city has increasingly faced other recurrent challenges, including heatwaves, infectious diseases, and environmental pollution (Resilient Cities Network et al., 2024). Floodwaters in Can Tho have been shown to carry similar pathogen concentrations to those measured in sewer water, posing substantial public health risks to exposed populations beyond the physical hazard of flooding (Nguyen et al., 2017; Huynh et al., 2019).".*

Regarding aquaculture, while it is an important economic activity in the Mekong Delta, it, along with other economic activities not analysed here, was deliberately excluded from the area description to avoid raising expectations on results that this work does not address.

Data used for this analysis is quite outdated, as it was collected in 2011. Considering the highly dynamic urban population, the fast pace of urbanisation, the increasing frequency and intensity of flooding, as described by authors, this is a major limitation of this study. It needs to be discussed critically in a standalone limitations section.

R25: We acknowledge that the flood loss observation data from 2011 represents a limitation of this study, representing past conditions that have since evolved. However, it is important to note that this dataset is not used to characterise current exposure directly, but rather to calibrate the flood impact models, which are then applied to more recent exposure data. Population data were obtained from the Can Tho city Statistics Office (2018), and vulnerable population figures (children below 5 years and seniors above 65 years) were resources from the General Statistics Office of Vietnam (GSO, 2020). Both provide a more recent reflection of the current urban conditions. This was already mentioned in Section 2.3.2. Exposure Data (Buildings, Population).

We agree, however, that the temporal mismatch between calibration data and exposure data introduces uncertainty in the results, and we added a critical discussion of this limitation:

- *"A key limitation of this study concerns the temporal scope of the data. The flood observations used to calibrate the economic flood risk model were collected during the 2011 flood event, whereas the pathogen concentration data were obtained from the 2016 event. Since then, Can Tho has undergone rapid urbanisation and infrastructure development, likely affecting exposure patterns and loss relationships. Although more recent data were used to characterise building and population exposure, the temporal mismatch between calibration of the loss models/pathogen concentration models and the exposure data introduces additional uncertainty into the analysis. Future studies should incorporate updated flood and damage observations to better reflect the present state of urban development and flood dynamics of the region.".*

Focus on building value and expected annual damage seems a little bit simplistic to capture economic risk, as livelihood strategies, assets, occupation, etc, need to be considered as well. It would be good to address this in the discussion and/or limitations section.

R26: We agree that building damage alone does not capture the full spectrum of economic risk. As a multi-dimensional phenomenon, flood-related economic loss also includes livelihood disruption, damage to productive assets, business interruption, and other indirect impacts that extent beyond structural damage. We focus on residential building damage as a measure of direct economic loss, as it follows well stablished and documented loss modelling approaches, where Chinh et al. (2017) is used as it mainly provide the observational basis for our loss model calibration in Can Tho, and where Scheiber et al. (2024) used the Expected Annual Damage (EAD) as a mean to estimate monetary losses due to damage to residential buildings in HCMC, Vietnam. Indirect losses are important but are more difficult to quantify and attribute consistently to our available data and empirical basis, and therefore lie beyond the scope of this analysis., We clarify this as a limitation as responded in R22.

Pathogen concentration in flood waters is modelled to appropriate disease risk, but what about household-level drinking water treatment and hygiene behaviour that could mitigate, reduce, eliminate the risk altogether? Authors are encouraged to consider this point in the discussion section, in the limitations, and/or follow up research suggestions.

R27: Household-level drinking water treatment and hygiene behaviour are relevant factors that could mitigate, reduce, or in some cases eliminate the disease risk associated with pathogen exposure in floodwaters. Our QMRA approach models exposure through accidental ingestion of floodwater during flood events, following Dorevitch et al. (2011) and Huynh et al. (2024), but does not account for individual or household-level behaviours. We agree that this represents a limitation of the current approach, as these could substantially alter actual infection risk. In this sense, our results should be interpreted as upper bounds under the assumption of unmitigated exposure, flagging the importance for future research. We added in the Results and Discussions:

- *"At the household level, drinking water treatment practices and WASH (water sanitation, and hygiene) behaviours constitute important determinants of individual pathogen exposure that could substantially mitigate infection risk (Huynh et al., 2024; WHO, 2016). Although these behavioural factors are not captured within the QMRA framework, their explicit inclusion in future modelling efforts would improve the representativeness of disease exposure and burden projections, particularly for vulnerable populations, including children under 5 years old.".*

The multi-risk assessment framework (figure 4) is certainly interesting. How flexible is it to include ad consider additional factors, such as property, health-seeking behaviour or prevention, personal or household behaviour, and drinking water, sanitation and hygiene (WASH)? This would be another important point for discussion.

R28: The multi-risk framework developed in this study was not designed to explicitly incorporate behavioural or preventive factors. However, the modular structure could potentially lend itself to extension, by the inclusion of additional assessments, e.g., Agent Based Model. Incorporating health-seeking behaviours, healthcare access, personal or household level prevention, and WASH practices would require supplementary data on behavioural responses, and, potentially, willingness to act indicators. This would align with scenario-based approaches already studied for economic flood risks, where private precautionary measures have been introduced as risk-modifying factors. To our knowledge, such integrated behavioural extension has not yet applied within a compounded economic-health risk framework, and recognise it as a valuable direction for future research, as more broadly responded in R22.

Exposure data used for this study relies mainly on data on individual buildings, incl. use, cost, structure, type and monetary losses. Isn't also household size a very important factor to consider in the economic impact that the loss of a house could have?

R29: Household size is indeed a relevant factor when considering the full economic impact of residential building loss, as larger households may face greater disruption and recovery costs relative to other values, such as content loss. However, these were not considered within the scope of our analysis, as we only focus on economic impacts on residential households emerging from building damages, following the approach established in Chinh et al. (2017), as a function of flood depth and structural characteristics. Household size was not included as a variable in the original loss model calibration. However, Chinh et al. (2016) correlated 23 predictors and 4 predictands for relative building loss (among others). The most strongly correlated variables to relative building loss were building value, content value, flood duration, and flood water depth, corresponding to basic depth-damage functions.

Similarly, we evaluated the inclusion of the following parameters: water depth, flood duration, frequency of flood events, and building value. We compared them and described the model predictions in the Supplementary Material (Bayesian Regression Models in S2.1).

Chapter 2.3.2 notes that the focus of this study are vulnerable populations, namely, children under 5 years old, and seniors older than 65 years old. This comes as a surprise, as it is not introduced in the introduction, and the study design lacks a justification. In the course of study, one of those two target groups (children) is mentioned, but not specified, or discussed. Effects on seniors are not reported at all. Authors are urged to clarify, specify and include respective results related to seniors.

R30: We agree that mentioning of the vulnerable populations was necessary. We refer to R22 to address this comment.

Results for both target groups are not only mentioned, but also specified for all stages of the QMRA modelling in Table 3, indicating the median values, as well as the lower and upper bounds for a more conservative reporting of the risks. The vulnerable group "seniors" is included under the results for "adults", as the parametrised inputs from Dorevitch et al (2011) do not differ between adults (under 65 years old) and seniors (over 65 years old). The results presented in the table were discussed, *referring to literature in the study area (or Vietnam) to compare values more effectively, including Huynh et al (2024), Nguyen et al. (2017), and Tran et al. (2024). We report and further discuss PHaR and EAC only for children under 5 years old as the most vulnerable population, as explained in the Introduction. The values for EAC were compared to Hoang et al. (2025).*

Datasets for this study combine data from 2011 with data from 2018 – in 2026. A reflection on implications on the model results, as well as on the interpretation of the relevance and timeliness would be a valuable addition.

R31: We agree with this observation. This was addressed in the revised discussion and limitations section (see also our reply to R25).

The section on QMRA (2.3.3) notes that "exposure to these (rotavirus A, e. coli) is assumed to occur through accidental ingestion of floodwater. This requires explanation and discussion. What about foodborne exposure, in the absence of sufficient hygiene for the handling of fish and shrimp, for example, as acquaculture is one of the main businesses in the Delta? Also, please note that other waterborne diseases expected in this study area, related to flooding, that also have diarrhoea as symptom, include typhoid fever and cholera. This may deserve a mention also.

R32: The assumption of accidental ingestion of floodwater as the primary exposure route is consistent with the QMRA literature for urban flood settings, as our study area is predominantly urban, and is supported by the intake rate parameterisation following Dorevitch et al. (2011) and Huynh et al. (2024), where activity- and age-specific ingestion rates during flood exposure are explicitly defined. We acknowledge, however, that foodborne exposure routes, such as those associated with the handling of fish and shrimp under insufficient hygiene conditions, represent an additional pathway that could contribute to infection risk in the Mekong Delta context. As economic activities were not part of our modelling framework, aquaculture-related exposure considered.

Regarding other waterborne diseases associated with flooding (and diarrhoea symptoms), we note that E. coli and rotavirus A are not the only pathogens responsible, noting in the introduction that rotavirus A is the most detected pathogen in Vietnam, and other pathogens including norovirus, Shigella, and Salmonella are also present (Anders et al., 2015). We chose to report on rotavirus A and E. coli as they were the only two pathogens that were tested in floodwaters after the 2016 event (Huynh et al., 2019, 2024). While we acknowledge the co-occurrence of pathogenic presence in floodwaters (beyond the two reported), we clarified in the results and discussions section that the scope of the QMRA does not consider co-infection or relationship between pathogens (WHO, 2016).

<u>Results and discussion</u>

The idea of a discussion section is to contextualise results, and provide a critical reflection with previous work. Please engage more in-depth with previous work to increase credibility of your work, highlight its value, and its shortcomings also, as well as the replicability. Please engage more with the topics opened up in the introduction, and the ones I proposed to consider, beyond that.

R33: In the revised manuscript, we have strengthened the discussion by engaging more directly with previous work where relevant, particularly in Section 3.2, where a larger body of comparable studies exists. For Section 3.3, however, the co-occurrence of economic and health risks has received much less attention in the literature, which makes direct comparison more limited. Even so, we have expanded the discussion of the methodological implications, the interpretation of the results, and the limitations *of the combined approach. We also added more reflection on the replicability of the framework and on how the present study builds on, and differs from, the topics introduced earlier in the manuscript.*

Under section 3.3. on intersecting economic risk and disease burden, it does not become clear how and why housing damage, and disease risks in children are used in this study. What makes children more special, susceptible, vulnerable, and why are they used in this analysis and not a different group? Note that children under the age of 5 years old are – globally – the most susceptible to infectious disease related to WASH, incl diarrhoeal diseases (see global burden of disease analyses in the Lancet journals) anyways, regardless of flooding.

R34: Children are indeed among the most susceptible population groups to WASH-related infectious diseases, including diarrhoeal diseases caused by rotavirus A and E. coli. This heightened susceptibility is explicitly reflected in the age-specific intake rates parameterised following Dorevitch et al. (2011) and Huynh et al. (2024), which provide the empirical basis for focusing on this age groups. Additionally, the availability of age-disaggregated data made it possible to derive results specifically for this vulnerable group. We also note that seniors above 65 years old were included as a second vulnerable group, though the results for this group follow similar spatial patterns and are therefore not discussed separately in detail.

The joint presentation of economic and health risk metrics already provides a meaningful combined picture of compounded flood impacts, from which the intersection of economic risks from housing damage and disease burden in vulnerable populations can be interpreted, without extending the analysis beyond the scope of what the data and models support.

What were advantages and disadvantages of models, how are they integrated, and what do we learn? There are a number of discussion points that – from a geoscience, global health, flood impact assessment, and community research perspective are missing, including

- More in-depth engagement with the spatial variation of compounded flood impact
  R35.1: The spatial variation of compounded flood impact is discussed in Section 3.3, where we identify wards with the highest and lowest intersecting economic and health risks. The results and discussion serve to further contextualise the observed spatial patterns, noting that the elevated compounded risks in Phu Thu (PTU), Thuong Thanh (TT), and An Binh (AB) wards reflect a combination of high building exposure, flood depth, and population density of vulnerable groups (focusing on children below 5 years old). Conversely, the consistently low risk wards in Ninh Kieu district benefit from proximity to flood defence infrastructure, mentioned but not included in the modelling design.

- Consideration of health burden beyond only just infectious disease exposure or physical health impact– as mental and social health are affected too, with tremendous impact on productivity, economic situation,
  R35.2: We agree that mental and social health represent important dimensions of flood-related health burden that extend beyond infectious disease exposure. These impacts and their cascading (indirect) economic consequences have been documented in other contributions. As noted in R22, these losses fall outside the scope of the current analysis. We do recommend them as a priority for future assessments.

- Discussion related to mitigation of impact based on healthcare services available and with that, the impact that flooding has on functionality of care, and accessibility, of health facilities, medication (also to be accessed in pharmacies etc). And why this matters from an economic perspective also
  R35.3: Disruption to health services and care-seeking behaviour has important economic implications. As addressed in R23, we have added a note in the discussion acknowledging that these are critical determinants of (an advanced) disease burden outcome not captured by our QMRA modelling.

- Related to this, a discussion of health inequalities, specific to different population sub-groups – and why children are particularly relevant in this context (or not)
  R35.4: As noted in R34, children under 5 years old represent the most documented vulnerable group for WASH and infectious diseases, including diarrhoeal diseases. Their inclusion is further justified by the availability of age-disaggregated intake rate data. The inequalities between seniors and children were presented in Results (QMRA model results), whereas the results for PHaR and EAC were only discussed for children. The discussion of WASH behaviours was expanded in R27, noting that future efforts should consider vulnerable populations.

- A discussion around one of the most important livelihoods and economic drivers in the area: aquaculture, and what role it plays in exposure to infectious diseases, and why economic impact of flooding is potentially tremendous beyond housing
  R35.5: As addressed in R32 and R34, aquaculture is an important economic activity and exposure pathway in the Mekong Delta. However, we exclude from the analysis to avoid raising expectations on results that this work does not address. The economic impact model focuses on residential building damage as a direct loss indicator following well established approaches in the literature, and the QMRA models exposure through accidental ingestion of floodwater. We acknowledge that the broader economic impact, including the disruption of livelihoods (including aquaculture), represents a gap. Including additional economic and non-economic losses for a full economic risk assessment was addressed in a note in the Results and Discussions.

- How the results can be used specifically for targeted and improved interventions, also related to the ongoing major efforts of Mekong River Commission and state actors in flood management and mitigation
  R35.6: The policy relevance of the results is discussed in the final paragraph of the discussion, where we note that the spatial risk estimates can inform targeted resource allocation by the health sector and incentivise private precautionary measures. We have expanded this in Results and Discussions to explicitly connect the findings to ongoing local/regional flood management efforts:
  - *"The ward-level co-occurring risk maps produced could further support the prioritisation of preparedness interventions by state actors and regional bodies, targeting resources where economic and health burdens converge most acutely, with the modular framework being transferable to other flood-prone urban settings.".*

  The results have the potential to support targeted awareness campaigns, equipping communities and individuals with knowledge of flood-related health risks, potential symptoms, and improve health-seeking behaviour, thereby reducing delays in care access and ultimately contributing to lower disease burden in the most vulnerable wards.

- Methodological discussions related to the value of this approach, strengths and weaknesses

R35.7: The primary strength lies in the integration of probabilistic flood simulations with independently calibrated economic and health impact models within a spatially explicit framework, enabling the identification of compounded risk hotspots that would remain invisible under single-sector assessments. Key limitations include the temporal mismatch between calibration and exposure data (addressed in R25), the restriction of economic risk to residential building damage, the assumption of unmitigated pathogen exposure in the QMRA, and the absence of behavioural and healthcare access factors. Together, these limitations suggest that the results should be interpreted as indicative of relative spatial risk patterns rather than absolute loss magnitudes.

- Where else could multi-risk assessment framework (figure 4) developed as part of this study be used?
  R35.8: The multi-risk framework developed here is designed to be transferable to other flood-prone urban settings, particularly in low- and middle-income countries where economic and health risks from flooding are disproportionately high and rarely assessed jointly. Cities in river deltas or coastal zones facing similar combinations of rapid urbanisation, inadequate sanitation infrastructure, and high flood exposure represent natural candidates for application.
  We have added a sentence to this effect in the discussion, noting that the modular structure of the framework allows for adaptation to different urban contexts provided that the necessary calibration data are available. Please refer to R35.6.

I miss a limitations section, that is really borne from this study. What kind of bias did the design of this study, the choice of models, the age of datasets (that different per factor investigated), the lack of information on spatial extent and spatial and temporal intensity of rainfall during monsoon season, etc., introduce? What would you expect from your analysis had you had access to such data?

R36: We agree that limitations were unclear in the text. We therefore added information: (1) related to the temporal mismatch between the 2011 flood loss observations and 2016 pathogen data used for model calibration and the recent exposure data; (2) the quantification of economic risk based exclusively on residential building damage, excluding indirect economic losses (e.g., livelihood, asset and occupation); (3) household-level WASH behaviours and healthcare access not considered in the QMRA modelling of the pathogenic distribution; and, (4) the focus on two pathogens and one exposure route, which likely underestimates the full infectious disease burden associated with flooding.

<u>Other</u>

Details on ethical considerations, ethics review process, approval, file number of ethics approval and approval date are missing. Please add these. It is expected for health-related research. Should authors have had an exemption from ethics approval, please describe this also.

R37: The survey data used in this study were collected as part of the WISDOM project (https://wisdom.eoc.dlr.de/). The survey was intended to capture building and content damage variables due to flooding (including flood depth, building value, and relative building loss), containing no personal health or behavioural information, hence it did not undergo an ethical approval from an ethics board.

Permissions were obtained from local administrative authorities, surveys were anonymised, and informed consent was secured from all participants by providing the study information and utilisation of the survey. The participants were provided an option to receive information on study outcomes and also a possibility to withdraw from the study. The pathogen concentration and disease parameters presented in this study are model-derived outputs based on previously published data, and do not *involve the collection of new observational health data from human subjects. Ethical considerations from the original data collection are documented in the respective source studies.*