Response to the Anonymous Referee #2

General Comments. This paper develops a county-level flood protection level (FPL) dataset for China on the basis of the prescriptions of the 2014 Chinese policy document Standard for flood control. It then analyses this against the amount of children and elders in the country, also by county. The paper is generally well written, and even though I do not think it can be considered particularly substantial as a research article (as the bulk of the work consists in essentially overlapping GIS datasets following a policy document), I believe the results are nevertheless interesting and useful to the community. Thus, in my opinion the article may be considered for publication in NHESS, although several improvements are necessary.

Accepted: Thanks for confirming the relevance of our manuscript and the suggestions for further improvement. We have thoroughly revised the paper, addressing your valuable comments and suggestions.

General comment 1.   The paper defines floodplain as the maximum extent of the 100-year flood map, and the exposed elements are then defined as the elements within that area. Should this refer to a defended or an undefended 100-year flood extent? Is there a reference to this aspect in the policy document, i.e. a guideline on how the actual quantification of exposed elements should be performed? This point needs to be clearly addressed in the article, as it will necessarily affect the estimation of FPLs. Moreover, taking into account that the 100-year hazard map used in this study (Rudari et al., 2015) already implicitly considers the existence of flood defences based on GDP, does its application impact the estimation of FPLs? Please discuss.

Accepted: Thank you for the suggestion. The 100-year flood map we applied, which was provided by Dr. Roberto Rudari from the CIMA Foundation, is explicitly based on undefended terrain. The undefended data were used instead of the defended one for two major reasons. First, the flood defenses were generally designed based on the potentially protected population and assets that would be under threat of floods prior to the defenses. Therefore, the exposed elements should be identified from the undefended flood maps, which provides a clue for inferring the flood defenses, as shown in the Chinese flood control policy. Second, flood defenses cannot ensure the protected areas' absolute safety; thus, the population and assets should not be excluded from flood exposure analysis. We now specify this important feature in the manuscript, also following General Comment 4 of Referee #3. Please check from *lines 88– 91 on page 4*.

Further, we clarified how we defined the flood exposure, also following General Comment 4 of Referee #3. The flood exposure was calculated as the elements within the maximum extent of the 100-year return period flood. This definition is consistent with the flood risk assessment by Shi et al (2015) and the flood exposure analysis by Jongman et al (2012), Du et al (2018), and Fang et al (2018). Please check from *lines 104–107 on page 5*.

References:

Du S, He C, Huang Q, Shi P, 2018. How did the urban land in floodplains distribute and expand in China from 1992–2015? Environmental Research Letters, 13(3): 034018.

Fang Y, Du S, Scussolini P, Wen J, He C, Huang Q, et al., 2018. Rapid Population Growth in Chinese Floodplains from 1990 to 2015. International Journal of Environmental Research and Public Health, 15(8): 1602.

Jongman B, Ward P J and Aerts J C J H 2012 Global exposure to river and coastal flooding: long term trends and changes Glob. Environ. Change 22 823–35

Shi PJ, Wang JA, Xu W, Ye T, Yang SN, Liu LY, Fang WH, Liu K, Li N and Wang M. 2015 World Atlas of Natural Disaster Risk (Heidelberg: Springer)

General comment 2.   The validation of FPLs is carried out not against a sample of actual flood protection infrastructure, but rather against local flood protection plans. Therefore, this exercise can be viewed more as a check on whether county-level flood protection policies are aligned with the national one from 2014, rather than an actual validation of computed FPLs. Although the authors acknowledge this limitation in the article, I am not convinced with statements such as "validating the policy-based FPLs as a reliable proxy for actual FPLs", which I find partly unsupported. I think the article would benefit significantly from a more robust validation with ground-truth data for a number of counties. Is this information for some counties not available or obtainable at all, e.g. with river basement management authorities?

Accepted: Thank you for the suggestion. Indeed, the only data we can find for the validation are documents of flood protection design, rather than the actual protection due to the lack of accessible ground-truth data. We agree that the flood protections in design documents are different from actual protection. However, we believe it is plausible to assume the actual protection of protection infrastructures that are completed and qualified to be equal to or higher than the designed standards, as a result of strict and tight control in the authoritarian administration of China. Following your critical comment and General Comment 3 of Referee #3, we dedicated additional efforts to enhance the validation, increasing the validation sample size from 51 counties to 171 counties. Now, as we specify in Section 2.4, the validation samples represent 7.6% of the surveyed Chinese counties, 34.0% of the exposed population, and 13.0% of Chinese exposed arable lands. We believe the expanded sample provides a substantially more solid base for the validation. Please check from *lines 129–131 on page 6* and *Supplementary* Table S1.

Besides, we have refined the selection process in the manuscript *(lines 121–129 on page 6)*. We selected the protection design documents for a relatively recent period from 2007 to 2012, neither too old that may be outdated nor too new that may be uncompleted and unqualified. Those documents would be kept in the validation data only if they stated that the design would be completed by 2015. Additionally, new flood protection design documents starting from 2015 were also employed, only if they stated the current (2015) flood protection standards.

Additionally, we revised the sentence about the validation statement. Now, it reads as: "This suggests that the policy-based FPLs is a valuable proxy for actual FPLs in China." *(line 12 on page 1)*

General comment 3. Still related to the comparison of county level plans and the national policy regarding protection level, can you please provide some additional information on how these counties were selected? It would be relevant to understand if these counties are representative of the different realities in China, particularly in terms of the variables defined in the policy (rural/urban, exposed population, arable land). You found an agreement in FPLs in 66.7% of the counties – can this be attributed in some way to specific properties of these counties, for example? Additional information on the validation counties and additional discussion on this would be useful.

Accepted: Thank you for the suggestion. The validation counties are selected based on the date of the flood protection design documents: the data should represent the flood protection of the year 2015. From accessible authority websites and literature, we found a raw sample of 304 counties with flood protection documents dating from 1998 to 2019. For the first round, we only selected the relatively new documents released from 2007 to 2012, neither too old that may be outdated nor too new that may be uncompleted and unqualified. Those documents were kept in the validation data only if they stated that the design would be completed between 2010 and 2015. A sample of 110 counties was selected from this round. For a second round, new flood protection design documents starting from 2015 were researched and these were kept only if they stated the current (2015) flood protection standards. Another 61 counties were selected then. Now, we have added how the validation sample is selected in the manuscript. Please check from *lines 121–129 on page 6*.

Additionally, we clarified the representativeness of the validation sample, also following your critical General comment 2 and General Comment 3 of Referee #3. With an expanded validation sample from 51 to a total of 171 counties, the validation data include 122 urban counties (19.1%) and 49 rural counties (3.1%). These represent 34.0% of the total exposed population and 13.0% of Chinese exposed arable land. Thus, we believe the validation counties can now be taken as representative of general Chinese territory. Please check from *lines 129–131 on page 6*.

Specific comments

Specific comments 1. Title: I feel that the use of "social divergence" raises a reader's expectations above what is actually presented in the article, which is limited to age groups. Please adjust the title to reflect this, or otherwise expand the analysis to include other factors that influence social vulnerability – the latter would certainly be more insightful and make the article more interesting.

Accepted: Thank you for the suggestion. We have expanded the social divergence to include the exposed rural and urban population following your critical comment. Accordingly, we revised sections 3.3 and 3.4 *(lines 219–222 on page10 and lines 240–244 on page 11)*; and added the supplementary Table S3 for the urban and rural population. However, the paper still does not consider all the aspects of social divergence, due to data limitation, which is now further clarified in section 4.3 *Limitation and future perspectives (lines 333–336 on page 15).*

Specific comments 2. L37: Remove 'Each year' (I assume these are aggregate numbers for 1990-2017)

Accepted: Thank you for this suggestion. It is indeed average data. We revised the sentence *(lines 39–41 on page 2)* and now it reads:

> Between 1990 and 2017, floods in China averagely affected 149 million people, led to 2165 deaths, and caused an economic damage of US$ 34 billion per year (Du et al., 2019).

Specific comments 3.   L58: I do not fully understand what the second research question means, in the sense that the policy document does not make reference to demographics in the definition of FPLs, and so the answer to this is already known. Please clarify.

Accepted: Thank you for this suggestion. We clarified the second research question, also following General Comment 2 of Referee 3. Now it reads as: "Since the FPL policy does not consider population demographics, what are the implications for the protection of vulnerable social groups?" Please check from *lines 62–63 on page 3.*

Specific comments 4.   L65: My interpretation of Jonkman, 2013 is that it states the actual opposite of what you are saying in this sentence. For example, Jonkman, 2013 says that ": : : the actual protection levels could differ by more than a factor of 10 from the protection standard, and the effect on risk will be similar." Please discuss and revise.

Accepted: Thanks for this suggestion. We revised the sentence *(lines 68–70 on page 3)* and now it reads:

> Flood protection policies provide an opportunity to establish a large-scale FPL dataset (Mokrech et al., 2015) as they generally contain information on how a region should be protected from floods, although some authors suggest that the actual protection levels could differ from the protection standard from policy (Jonkman, 2013).

Specific comments 5.   Eq. 1: I find "GDP-weighted PopE" a poor name for a variable, as it is a bit long and at first sight it appears to be GDP minus: : : Please improve.

Accepted: Thanks for this suggestion. We also would prefer a shorter variable name, but this would require another abbreviation, while we think we have enough. We have changed it to "GDP weighted PopE".

Specific comments 6.   L119: Section 2.5 is unexpected and feels disconnected from what comes before in the article, because up to this point you have not yet stated that this is an analysis you will be doing. Is this cluster analysis meant to address a research question? Please contextualize beforehand, and when doing so provide an explanation on why this analysis is useful.

Clarified: Thank you for the suggestion. This section is associated with the first research question "What level of protection against river floods does Chinese policy imply across the country?" Based on the derived flood protection levels (FPLs), we can have a map and describe the distribution of the FPLs (high values and low values). More than that, the spatial pattern analysis of the FPL data quantitatively shows where the significant high/low values are located and how the high/low values are clustered. We think this method is important, as it adds a rigorous spatial analysis. Meanwhile, it can present the regional risk: a high-FPL county should

also be at risk if its surroundings suffer severe flooding. We added an explanation of this at *lines 135–138 on page 6.*

Specific comments 7. L163: Unclear which previous studies this sentence refers to. Is it only Scussolini et al., 2016? Please clarify.

Accepted: Thank you for the suggestion. This sentence has been clarified as follow *(lines 182–183 on page 8)*:

> Therefore, Chinese FPLs are probably underestimated in previous studies (Scussolini et al., 2016).

Specific comments 8. L197: Because FPLs also change over time but only current FPLs are considered in this section, I am unsure about the usefulness of the analysis carried out here. For the same reason, I also find this section title a bit misleading. Please improve and clarify.

Clarified: Thank you for the suggestion. Indeed, both FPLs and population change over time. In this section, we focus on how the exposed population changes if flood protection is kept constant over time. Such a method clearly and directly shows how the total population and the demographic characteristics changed in areas of currently different flood protection levels and how the change rate varied between current high and low flood protection levels. We believe such a strategy can clearly indicate the importance of considering population dynamics and demographic characteristics in the flood protection policy, which is critical for improving the policy.

Specific comments 9. L235: This could also simply be the result of FPLs being calculated on the basis of present-time exposed population, couldn't it? We do not have information about FPLs in 1990; therefore, stating that a faster increase in exposed population may have occurred in these counties because in the past their FPL was already high seems speculative. Please discuss.

Accepted: Thanks for the suggestion. We have revised this sentence to avoid confusion. Now the sentence reads as follows *(lines 265–267 on page 12)*:

> The possibility of a similar outcome should be considered in China, as suggested by the faster increasing trend of the exposed population in the high-FPL counties than in the low-FPL counties.

Specific comments 10. Table 1: Note at the bottom is unclear.

Accepted: Thanks for the suggestion of Table 1. This note has been clarified. Please check from *lines 514–518 on page 21*, or as below.

Table 1. Urban and rural standards for evaluating the flood protection level (FPL) (source: Standard for flood control GB 50201-2014)

Urban FPL Indicators		Urban FPL (Return period, years)	Rural FPL Indicators		Rural FPL (Return period, years)
Population exposure (million)	GDP weighted population exposure* (million)		Population exposure (million)	Arable lands exposure (thousand ha)	
<0.2	<0.4	30–50	<0.2	<20	10–20
≥0.2	≥0.4	50–100	≥0.2	≥20	20–30
≥0.5	≥1	100–200	≥0.5	≥66.7	30–50
≥1.5	≥3	≥200	≥1.5	≥200	50–100

Note: * GDP weighted population exposure is the population exposure multiplied by the ratio between the relative per capita gross domestic product (GDP) and the national average.

***Specific comments 11.*** Figure 2: Remove "the" in y-axis label.

Accepted: Thanks for the suggestion for Figure 2. This label has been corrected. Please check from *lines 526–527 on page 24*, or as below.
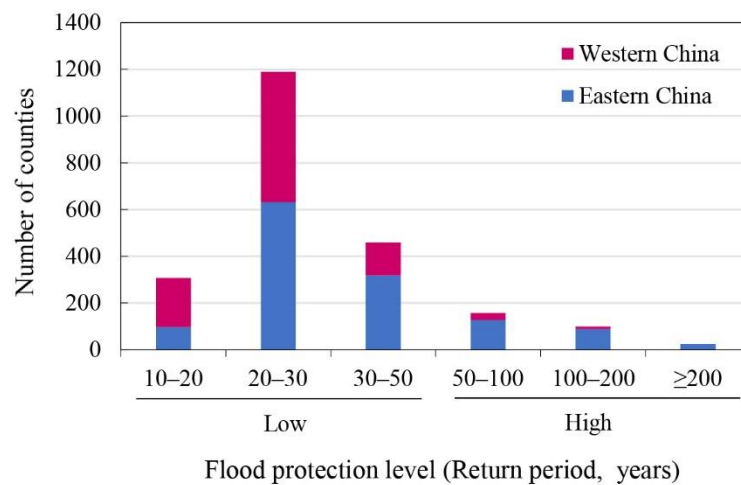
Figure 1 The number of counties with different flood protection levels. (The map of western and eastern China is shown in Figure 3)

Specific comments 12. Figure 5: In the y-axis label, replace "Exposure" with "Exposed population".

Accepted: Thanks for the suggestion. This label has been corrected. Please check from *lines 534–535 on page 27*, or as below.
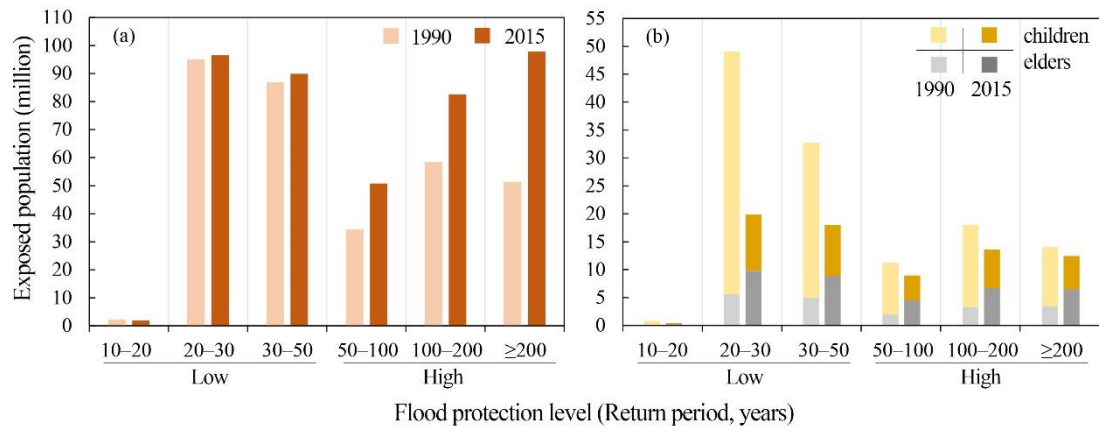
Figure 5 Changes in exposed total population **(a)** and vulnerable population **(b)** across different flood protection levels from 1990 to 2015.