

Response to the Anonymous Referee #3

General Comments. The objective of the paper is to develop and validates a Flood Protection Level (FPL) dataset for China, which is based on current Chinese policy on FPLs. Accordingly, base data and methodologies for its development are first discussed, and then results are critically analysed. Although the paper does not represent any significant improvement in research, it supplies relevant information for flood risk management in one of the biggest and most flood prone area of the world; and thus, it can be of interest for the journal audience. The paper is generally well written and organised; data, methods and results are quite well explained. However, before results can be published, shared and made available to the research community, I think that some conceptual aspects deserve more attention and clarification.

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 FPL generated by the dataset is a theoretical one (i.e. designed based) and not the real one. This must be very clear since the beginning of the paper and not marginally discussed at the end. Accordingly, authors should stress since the beginning why this information is useful, how it can be used for risk management, e.g. as a proxy of the flood risk in an area?

Clarify: Thank you for the suggestion. We have revised the paper accordingly in the *Introduction*. First, we further provide arguments for why the data is useful. Nowadays, flood risk assessment is drawing an increasing attention worldwide and playing a critical role in flood risk management. However, flood protection information, an essential element of flood risk estimates, is rarely available in reality, which dampens a reliable analysis of flood risk and its applications. Particularly for China, the only nation-wide available data is from the global database FLOPROS (Scussolini et al., 2016), which has a raw resolution of provinces. On the other hand, the Chinese flood control policy clearly stated how an area should be protected according to the exposed elements. We believe this information is useful for risk analysis and management. Please check from *lines 20–58 on page 1–3*.

Second, we added how the newly developed database can be used for risk management, also following your Minor Comment 9. 1) Authorities can use this database to check if the relevant counties are protected properly. 2) Flood risk assessment could be conducted considering the developed flood protections. 3) The policy-based FPL can be an important foundation for relevant researchers to develop a more reliable FPL dataset of China and for the rest of the world. 4) It can help to reveal potential social divergence by combining the policy-based FPL with demographic data, which can further improve the flood protection policy, as indicated by the relevant analyses in this study. We have discussed this issue in Section 4.3. Please check from *lines 316–321 on page 14*.

General Comment 2. With respect to the last point, the second research question could then be changed in: Is FPL representative of the real risk in the area or its definition/evaluation should be changed? In fact, the present second research question (i.e. does the FPL policy take into account relevant demographics of the exposed population, such as elders and children who are known to be most vulnerable to floods?) is not clear at this point of the paper (i.e. why exactly this question?) as it is too much linked to an evidence that comes out only at the end of the manuscript

Accepted: Thank you for the suggestion. Also following Specific Comment 3 of Referee #2, we have revised the second research question to “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*.

General Comment 3. The validation process is very weak, so I do not agree with authors that theoretical FPL agrees with real one very well (see section 4.3). The validation process was carried out only for 51 (about 2%) out of 2237 counties and a match was observed only for 66.7% of the counties (about 1.5%). This has important implication on the use of results (see comment 1)

Accepted: Thank you for the critical suggestion. We have made the following two efforts to strengthen the validation, also considering General Comment 2 of Referee #2.

First, we increased the validation sample size from 51 counties to 171 counties. Now, the match ratio between the FPL database and the validation data is 53.2%. It can reach 90.1% if we apply a free bound of one protection level (the protection levels are considered as a match if the difference is zero or one protection level). Please check from *lines 170–175 on page 8*, and *Supplementary Table S1 and Table S2*.

Furthermore, we also discussed the representativeness of the validation sample. It represented 34.0% of the total exposed population and 13.0% of exposed arable lands in China. Thus, we believe the expanded samples should provide a relatively more reliable validation. Please check from *lines 129–131 on page 6*.

General Comment 4. The calculation of FPL is based on the assumption that the exposed area coincides with the 100 years return period flooded area. As this critically affects the estimation of FPL, authors should explain the reasons of this assumption. Moreover, how such an area was derived? does the modelling consider or not the existence of flood protections? What this implies?

Accepted: Thank you for the suggestion. We clarified the flood exposure definition and the employed flood data, also following General Comment 1 of Referee #2.

First, we calculated the flood exposure 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*.

Second, the 100-year flood map we applied is undefended, which was provided by Dr. Roberto Rudari from the CIMA Foundation. This dataset was produced based on hydrological and hydraulic models at a resolution of 1 km, which were validated against historical floods. And it has been effectively used for analyzing China's urban land expansion (Du et al., 2018) and population dynamics in floodplains (Fang et al., 2018). The undefended data were used instead of the defended one for two major reasons. First, the flood defenses were designed based on the protected population and assets, 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. Please check from *lines 88–91 on page 4*.

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 P J, Wang J A, Xu W, Ye T, Yang S N, Liu L Y, Fang W H, Liu K, Li N and Wang M. 2015 *World Atlas of Natural Disaster Risk* (Heidelberg: Springer)

Minor comments

Minor comments 1. line 21 “With the emergence of large-scale flood models, the necessity to quantify FPLs has increased in recent years” the cause-effect relation is not clear to me, could authors comment more on this?

Accepted: Thanks for your suggestion. We have revised this sentence accordingly (*lines 22–23 on page 1*). Now it reads as:

With increasing focus on large-scale flood risk assessment, which also depends critically on flood protection information (Ward et al., 2017; Alfieri et al., 2017; Winsemius et al., 2018), the necessity of quantifying FPLs has increased in recent years.

Minor comments 2. line 27 what “improved FPLs” means?

Accepted: Thank you for this suggestion. It means high FPLs. We revised the sentence (*line 29 on page 2*) and now it reads:

High FPLs reduce the frequency of floods in flood-prone areas and decrease flood risk (Ward et al., 2013).

Minor comments 3. line 37 “China is one of the countries that experience the most serious floods and the fastest urbanization. Each year between 1990 and 2017, floods in China affected 149 million people, led to 2165 deaths, and caused an economic damage of US\$ 34 billion” I guess these figures refer to average data

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).

Minor comments 4. line 85 “It originally has a spatial resolution of 100 m and is aggregated to a 1 km resolution to match the flood depth data, further to get population exposure using methods described in Fang et al. (2018)” I think that a brief explanation/recall of how the data were elaborated is required.

Accepted: Thanks for the suggestion. A brief explanation and relevant references were added. Please check from *lines 104–107 on page 5*.

Minor comments 5. line 151 “In 34 (66.7%) out of the 51 verification counties, the FPLs agree with the local official protection plans (full information in Supplement). The FPLs in the dataset are overestimated in four counties and underestimated in five counties” what about the other 8 counties?

Accepted: Thank you for the suggestion. It was a mistake. We revised the sentence with an expanded validation sample (*lines 169–172 on page 8*). The sentence now reads as follow:

In 91 (53.2%) out of the 171 verification counties, the FPLs agree with the local official protection design documents (Supplementary Table S1 and S2). The FPLs in the dataset are overestimated in 20 counties (11.7%) and underestimated in 60 counties (35.1%).

Minor comments 6. line 176 “These counties within the “low-high” FPL clusters can be more vulnerable when they are needed to sacrifice to protect their surrounding large cities that are more expensive to be flooded” not clear, more vulnerable than what? Could authors explain?

Accepted: Thank you for this suggestion. We have revised the sentence (*lines 196–199 on page 9*) and it reads as follows:

These counties within the “low-high” FPL clusters can be vulnerable to floods when they are needed to sacrifice to protect their surrounding large cities that are more expensive to be flooded (Wang et al., 2016). For instance, in China, flood detention zones are planned in rural areas to protect surrounding cities in the Yangtze River and Huaihe River Basins of China (Du et al., 2020).

References:

Du, S., Shen, J., Fang, J., Fang, J., Liu, W., Wen, J., Huang, X., and Chen, S.: Policy delivery gaps in the land-based flood risk management in China: A wider partnership is needed, *Environmental Science & Policy*, 116, 128–135, <https://doi.org/10.1016/j.envsci.2020.11.005>, 2021.

Minor comments 7. line 217 “The newly developed data show that almost one third (33.1%, 741) of the evaluated Chinese counties are protected with a ≥ 30 -year FPL” should be protected.... It’s a theoretical FPL

Accepted: Yes, it’s a theoretical FPL. Accordingly, this sentence has been revised as follows:

The newly developed data show that almost one third (33.1%, 741) of the evaluated Chinese counties are should be protected with a ≥ 30 -year FPL, while this FPL is only in 5 (14.7%) out of 34 provinces in the FLOPROS (Scussolini et al., 2016). (lines 248–250 on page 11)

Minor comments 8. line 224 “For instance, global flood risk assessments show huge flood risk across Chinese provinces both in current condition and future scenarios (Willner et al., 2018a), which are considered to further propagate a devastating indirect impact to other countries through the global trade and supply network (Willner et al., 2018b). However, those global assessments are based on the FLOPROS database, which significantly underestimate Chinese FPLs, e.g., presenting Beijing with a 20-year FPL, which should be 200 years in the newly developed result (Fig. 3) and in the local official document (full information in Supplement). The real flood risk should thus be much lower than the estimates in previously studies if the new FPL is considered” The authors cannot made this statement as the correspondence between theoretical and real FPLs have been evaluated only for 51 out of 2237 counties; the case of Beijing is a fortunate one where a perfect match occurs. But, can authors exclude that counties exist where there is not a FPL at all in practice, in front of a theoretical FPL, or a real FPL that is lower to designed based one? In this case, the risk can be underestimated. Please, comment.

Accepted: Thanks for the suggestion. We have increased our validation sample size from 51 to 171, also following your critical General Comment 3 and General Comment 2 of Referee #2. And now the validation samples represent 7.6% of the surveyed Chinese counties, 34.0% of the exposed population, and 13.0% of Chinese exposed arable land. Besides, the FPL dataset has a higher resolution than the FLOPROS; the former is based on counties and the latter is based on provinces. Therefore, we believe the FPL data are a valuable proxy. Please check from lines 129–131 on page 6.

Meanwhile, the reason for the overestimation of Chinese flood risk mainly results from an underestimation of Chinese protection against flood. Therefore, we have compared the difference between FPL and FLOPROS by Paired Sample T Test. Please check from Supplementary Table S4. Furthermore, we have revised the sentence (lines 257–259 on pages 11–12) and it reads as follows:

However, those global assessments are based on the FLOPROS database, which is significantly lower than the policy required FPLs as indicated by the Paired Sample T Test ($p < 0.01$, supplementary Table S4). For instance, FLOPROS presented Beijing with a 20-year FPL, while it should be 200 years according to the Chinese protection policy (supplementary Table S1).

Minor comments 9. line 245 “A neglect of the real-world flood protection lagging behind the policy-based flood protection can distort the selection of adaptation measures” this is exactly the point. Then, how theoretical FPL can be used (see general comment 1)?

Accepted: Thanks for the suggestion. Also following your General Comment 1, we added a discussion on how the theoretical FPL can be used:

1) The authorities can use this database to check if the relevant counties are

protected properly. 2) Flood risk assessment could be conducted considering the developed flood protections. 3) The policy-based FPL can be an important foundation for relevant researchers to develop a more reliable FPL dataset of China and the rest of the world. 4) It can help to reveal potential social divergence by combining the policy-based FPL with some social data, which can further improve the flood protection policy, as indicated by the relevant analyses in this study.

Minor comments 10. line 266 “Such a strategy, however, may aggregate flood risk because the less protected areas coincide with high social vulnerability that is caused by a disproportional distribution of vulnerable people, particularly elders” what authors mean with “aggregate flood risk”

Accepted: Thanks for your suggestion. It was unfortunately a misspelling. It should be “aggravate”, which was corrected (*lines 299–301 on page 13*).

Minor comments 11. line 300 “This study thus agrees with the argument of Scussolini et al. (2016) that flood protection policy is a valid proxy for actual FPL” I do not agree, see general comment 4

Accepted: Thanks for the suggestion. We revised the paper accordingly. First, we expanded the validation sample size from 51 counties to 171 counties, also following your insightful General Comment 3. Second, we revised the statement as follows:

This study thus agrees with the argument of Scussolini et al. (2016) that flood protection policy is a valuable proxy for actual FPLs. (*lines 341–342 on page 15*)

Minor comments 12. Figure 1 I think that a full description of the framework is required in the text, i.e. in Section 2.1, to support readers in the full comprehension of following contents.

Accepted: Thanks for your suggestion. A full description of the framework has been added. Please check from *lines 78–84 on page 4*.

Minor comments 13. Figure 3 colours used for the FPLs 30-50 and 50-100 cannot be distinguished in the figure.

Accepted: Thanks for the suggestion. *Figure 3* has been improved accordingly. Please check from *lines 528–531 on page 25* or as below.

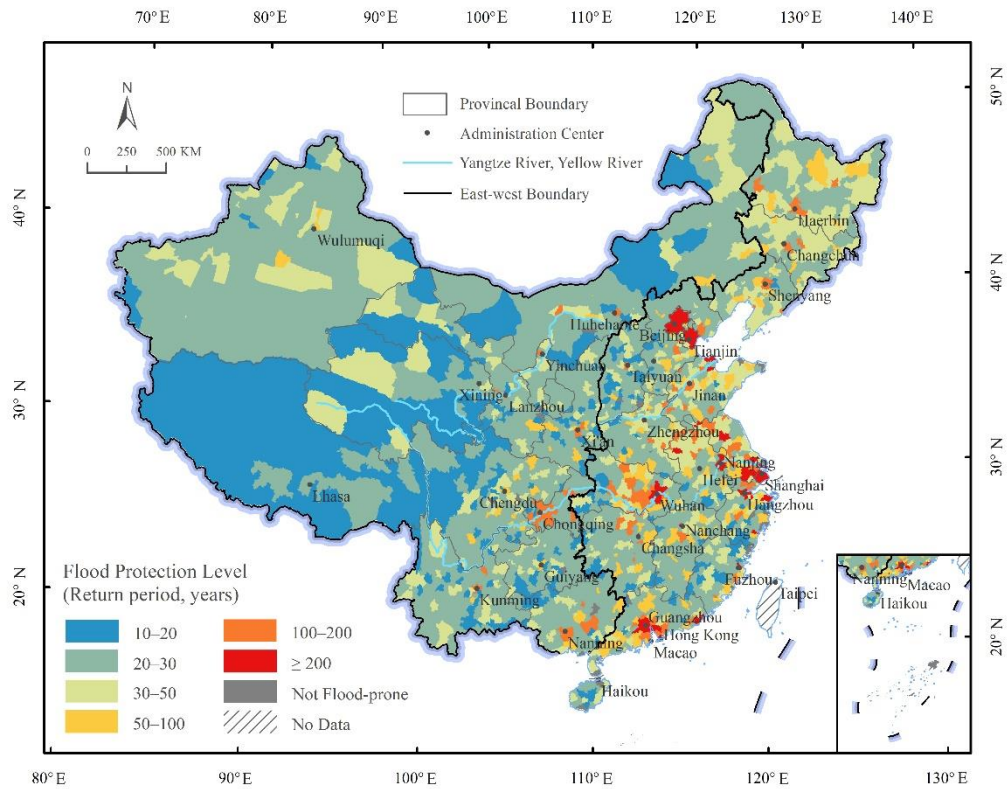


Figure 3 Flood protection level (FPL) for Chinese counties. The FPL is limited to the scope of floodplains but plotted to cover the entire counties. The data should only be viewed as a proxy of the actual FPLs, not equating to the actual FPLs. The Shapefile format data are available as a supplement.