Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2018-328-AC3, 2019

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Probabilistic seismic hazard analysis using logic tree approach – Patna District (India)" *by* Panjamani Anbazhagan et al.

Panjamani Anbazhagan et al.

anbazhagan2005@gmail.com

Received and published: 12 April 2019

Response to Reviewer 3 General Comment: - Journal: NHESS Title: Probabilistic seismic hazard analysis using logic tree approach – Patna District (India) Author(s): Panjamani Anbazhagan et al. MS No.: nhess-2018-328 The article titled "Probabilistic seismic hazard analysis using logic tree approach Patna District (India)" utilize logic tree technique to conduct PSHA study for Patna District, India. Authors employ different branches in the logic tree for PSHA calculations to handle the epistemic uncertainties. Although the work is extensive, and the exerted efforts are great, this paper still needs many clarifications, so it can be accepted for publication. It is not well organized, and, in many parts, it is non-properly sequenced with non-threaded paragraphs, leaving the reader confused and suffering to catch the idea. The English

language of the paper is poor and negatively affects the understanding of many paragraphs. English needs to be revised critically. Abbreviations should be mentioned at its first appearance. Avoid using the same abbreviation for two different terms (e.g. SA is used for spectral acceleration and for study area). What are SSA, MBT, MCT, S60,: :.etc. All abbreviations should be defined at their first appearance in the text. All localities, faults and geological structures mentioned in the manuscript should be shown on maps. I could not appropriately follow the seismotectonic part of the area due to lack of such illustrations. Response: - The authors would like to thank the reviewer for his valuable comments which helped us in reviewing the manuscript. The manuscript has been revised thoroughly for English and flow has been maintained to make it easy for the readers. Abbreviations have been provided at the first place. SA is only used for the spectral acceleration in the revised manuscript. The faults mentioned in the manuscript has been shown properly and quality of the seismotectonic map has been improve. Introduction Comment 1: - Page 1, lines 20-21: Which gap? Please provide more explanation. Response: - It is the Himalayan seismic gap and detail explanation is given in Bilham and Wallace (2005); which is also mentioned in the manuscript. Change in the manuscript: The Himalayan seismic gap (Bilham and Wallace, 2005) and thick soft soil sediments makes the scenario more dangerous for cities close to Himalayan region. Comment 2: - Page 2, lines 3-5: Very accurate sentence, but nothing is carried out in the end. Why this sentence is written here? Response: - This sentence is mentioned to justify the need of the hazard analysis for the Patna city and in the present study an updated map, and methodology used to determine the hazard value at bedrock for Patna city. Comment 3: - Page 2, line 27: I could not understand "Maximum magnitude has been determined weighted mean using increment : : :: : :." Response: - This statement has been revised and given below. Change in the manuscript: Maximum magnitude has been determined using weighted mean considering three methods as increment factor on maximum observed magnitude, Kijko and Sellevoll (1989) and regional rupture characteristics (Anbazhagan et al. 2015b). Geology, Seismotectonics and seismicity of the study

area (SA) Comment 4: - Page 3, line 8: coordinates here are for a point, it is not for an area. Response: - The statement has been changed as follow Change in the manuscript: The present study area has covered the longitude 84.6-85.65°E and latitude 25.2-25.8°N Comment 5: - Page 3, line 29: "and published literatures" give references. Response: - It has been mentioned in the revised manuscript. Change in the manuscript: The seismotectonic map was developed by considering 500 km radius from Patna district boundary by considering linear sources (faults and lineaments) from SEISAT and published literatures (e.g. NDMA, 2010; Nath and Thingbaijam, 2012; Kumar et al., 2013). Comment 6: - Page 4, lines 1-3: Authors should show the priority scheme in selecting the earthquake from each data base. I mean if the same earthquake is available in more than one database, which one will be selected? Which magnitude scale from which database has the first priority and which has the second and so on? Is the same magnitude scale for the same earthquake at different database yield the same value? All the above queries should be clarified in detail. Please show the start and end time of the catalogue to be able to assess its reliability. Response: - The events have been selected from all the mentioned agencies. The duplicate events have been deleted and further the magnitude has been homogenized to moment magnitude scale. This is mentioned in the revised manuscript. Further the start and end time of the catalogue is also given in the revised manuscript. Change in the manuscript: The events have been selected from all the mentioned agencies. The duplicate events have been deleted and further the magnitude has been homogenized to moment magnitude scale. Comment 7: -Page 4, lines 15-18: Please revise the earthquake numbers in each magnitude range as their sum should be 818 as mentioned in Page 4 line 9. Response: - Apology for the same. The correct number has been mentioned in the revised manuscript. a and b parameters Comment 8: -This is the most confusing part of the manuscript. In this section the a and b values are calculated for two regions (I and II). What is the role of these two areas and their seismicity parameters in the hazard calculations? The classical method used 178 seismic sources and the zoneless method used 7 area

seismic zones. Why this is interfered in the current study. Secondly, the magnitude of completeness should be calculated before evaluating the seismicity parameters as GR parameters should use complete data only. Response: - The seismic study area has been divided into two regions based on the seismicity. That is why a and b values are calculated for two regions (I and II). The hazard values are calculated using classical approach in which 178 seismic sources have been used as input parameter, whereas, in the zoneless approach, 7 areal sources have been used which are delineate based on the seismicity parameters. a and b values have been calculated considering two ways one considering magnitude of completeness and other period of completeness. Comment 9: - Magnitude of completeness Page 5, line 12: This great difference in the Mc values casts doubt on the calculated values. Please explain why different methods have such different outputs. Also justify the great difference in a and b values in lines 17-19. B values of 0.149 and 0.176 are not physically accepted. Again, it is not clear how the authors used the a and b values shown in this section in the hazard calculations? Response: -We agreed with the reviewer, the difference in Mc values is due to the different algorithms used, which is also explained in the revised manuscript. However, we used these nine different methods to estimate the uncertainty in the seismicity parameters. The lower b-value is observed as it is calculated based on the magnitude of completeness, but it is not used for the analysis and is also explained in the revised manuscript. Change in the manuscript: The lower b-value is observed as it is calculated based on the magnitude of completeness which may be due to the change in the algorithm as it selected the completed magnitude as minimum observed magnitude. This is not used further in the hazard calculation. Maximum magnitude estimation (Mmax) Comment 10: - Page 5, line 32: "based on b values" to add 0.5 based on b value, b value should range between 0.9 and -1.0, which is not the case here. Response: -The calculated and adopted “b-values” is in the range of 0.8 to 1.0, hence as per the suggestion adding 0.5 to maximum magnitude observed is justifiable. Comment 11: - The authors used the region-specific rupture technique to calculate Mmax and provide it the maximum weight. The technique depends on

the ratio between the rupture length and the total fault length. My questions are: 1- Is the seismic record enough to be sure about the above ratio? The answer is NO as the authors themselves clarified when they justify the use of zoneless method, stating that "many sources given in Figure 1 are not well studied to prove its seismic activity". This raises great uncertainty on the maximum magnitude calculated for these seismic sources. 2- Is there any possibility to rupture the entire fault length in one earthquake? Recent studies suppose that the entire fault length will be ruptured in one earthquake when calculating the maximum earthquake. Response: -We agreed with the reviewer but seismic sources we used are 178 in number which is enough as per our knowledge to justify the ratio and which can also be observed from the trend shown in Anbazhagan et al. (2015 a). However, in addition to that we also used other methods which is based on the seismicity of the region i.e. Kijko method and incremental method. All the sources used in the present study are from published literature and mentioned in the manuscript. There may be a possibility of total rupture of total fault length, however, as far as Himalayan seismotectonic is concerned, no study exists on this context as per knowledge. We may consider the total rupture in our future study. 8.1 Classical approach Comment 12: - Page 9, line 27: Authors used 178 seismic sources. The seismicity of many of these faults are not well studied. It is not clear how the seismicity parameters are calculated for each single source. It is well known that GR model cannot be used to calculate a and b values for single faults. Slip rate could be used but with many not well studied sources, the results should be at least uncertain. Using logic tree does not mean ignoring use the right input parameters for each method. Response: -We agreed with the reviewer that seismicity of the sources may not be properly studied, hence, due to that we used a well-defined approach explained by Anbazhagan et al. (2009). As far as this study is concerned, we did not calculate GR “a” and “b” parameter for single fault. Slip rate can be used but for determining the hazard value, we used well-defined algorithm defined by Cornell (1968), which does not require the same. Zoneless approach Comment 13: -Page 10, line27: use return period instead of "frequency of exceedance" Four models (figure 4)

using zoneless approach (Frankel, 1995) Response: -It has been replaced, as per the suggestion. Comment 14: -Page 11, line 15: the return period 85 years (of what? This is most probably PGA) Response: -Yes, it is the defined for PGA. Comment 15: -Page 11, line 19: From which model the deaggregation plot is calculated? Or the authors used weighted deaggregation values based upon the weighs given for each of the four models. This should be very clear. Authors should explain why the results of the two methods are completely different in terms of hazard values and terms of the change in the spatial distribution (many low hazard areas in one method show very high hazard in the other method). This should be justified, as it is not enough to say for this the logic tree is created. A mistake could be done in the calculation or a method is not adequate for the region. Therefore, it is better to justify the use of zoneless methods. Response: -The deaggregation has been calculated by considering the weighted mean from all the four models. This is mentioned in the revised manuscript. As these two methods have different input values, hence the results are different that is why logic tree approach has been used to reduce the uncertainty. The difference in results in explained in more details in the revised manuscript. The used of zoneless approach is due to spatial variability of the seismicity of the region and to estimate the hazard value where seismic source is not well studied. This is also explained in the revised manuscript. Change in the manuscript: The deaggregation has been calculated by considering the weighted mean from all the four models. Comment 16: -Page 12, line 5: Please add for 10% probability before "The PGA values" Final hazard map using logic tree Response: -As per the suggestion, it has been added. Comment 17: -Page 12, lines 26-27: As the high hazard values are related to the East and West Patna Fault, then, why the classical hazard values which are more related to the faults show very much less values?? Authors compared their results with previous studies. I recommend comparing the results of each method with the recent observations and with the previous studies to show a reason why the results are very inconsistent. If the current results are accurate, authors should recommend to change IS 1893 (2002) in Patna as the current hazard values highly exceed its summit. Figure 1 is very unclear

and need to be provided in a higher resolution way. Response: -As per the results and calculations, PGA is higher near to the East and West Patna Fault (See Figure 8). As per the suggestions, the values form all the methods are also compared in the revised manuscript. Also detailed comparison with previous studies are revised in the revised manuscript Figure 1 has been revised as per the suggestion and detailed source are given. Change in the manuscript: It has seen from the mean deaggregation plot that the motion for 6.0 M_w at 40 km hypocentral distance, 6.0 M_w at 15 km hypocentral distance and 6.0 M_w at 25.25 km hypocentral distance is predominant in case of Cornel's, Areal and Frankel's approach respectively considering 2 % probability in 50 years. However, the motion for 5.5 M_w at 50 km hypocentral distance, 5.75 M_w at 20 km hypocentral distance and 5.75 M_w at 30.3 km hypocentral distance respectively predominant in case of Cornel's, Areal and Frankel's approach. The PGA values varies from 0.08 to 0.43 g, 0.29 to 0.41 g and 0.26 to 0.36 g in case of Cornel's, Areal and Frankel's approach respectively considering 2 % probability in 50 years. Whereas it from 0.04 g to 0.18 g, 0.09 g to 0.16 g and 0.09 g to 0.16 g respectively considering 10 % probability of exceedence in 50 years in case of Cornel's, Areal and Frankel's approach. ==== END====

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-328/nhess-2018-328-AC3-supplement.pdf

---

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-328, 2019.