To: Natural Hazards Earth Systems Discussion

Re:Niger's Delta vulnerability to river floods due to sea level rise
by Z. N. Musa et al.

Response to anonymous reviewer #1

Thank you for taking the time to read the discussion paper. Please find below, the answers to your questions and comments. We value the comments received as they point out the issues that need to be addressed in order to improve the paper.
Hera are the answers:

Comment 1: *This paper demonstrates an interesting approach to assess vulnerability to river flooding due to sea level rise. An important approach which brings new information on comparing two coastal vulnerability methodologies. The text reveals high skills and knowledge of the authors the introduction is very rich in sources, very informative. The methodology is good, informative and explanatory, describing the importance of each indicator used. The data is rich which might be also of interest to the readers.*

Authors' answer: Thank you for the appreciations on the data used and the importance of the methods used for flood vulnerability assessment.

Comment 2: *The results and discussion chapter is good, but very brief, I suggest to the authors to add a more descriptive approach with its scientific analysis of pros and cons of the approaches taken.*

Authors' answer: As requested, we think the reviewer is right and we would like to extend teh explanation and to the following:
(Remark: highlighted text is the new added one, Table 5 is new as comapred with the discussion paper, hence shown at the end of this document.)

"In order to calculate the $CV_{SLR}I$ for the 450km of the Niger delta coast, 54 coastal segments are considered. The segment division is based primarily on three main elements; elevation (fig. 2); change in slope (fig. 3); and the presence of large estuaries. The segments are represented in fig.4. The sizes of the segments differ from one another in length, however on average the segment width is 4km inland.

For each coastal segment, the exposure, susceptibility and resilience indicators are calculated and ranked. The range of results for the Niger delta coastal segments are normalized using equation 4 and classified into five vulnerability classes (very low, low, moderate, high and very high) based on percentile ranges. Accordingly, the calculated results for the Niger delta gives the following ranges of vulnerability: 0.0-0.02 ('very low'), 0.02-0.04 ('low'), 0.04-0.09 ('medium'), 0.09-0.13 ('high'), and 0.13-1.0 ('very high'). As an example of the indicator ranking for the Niger delta coast segments 1-4, 52 and 54 are selected to be presented, as shown in table 5. The most vulnerable segment, number 52 has a low slope (<1%), low topography (3-5m), estuaries, very high hydraulic conductivity (>81m/day), very high population density (>800 people/km^2), and settlements within 100-200m of the coast. These attributes have thus made it highly vulnerable to SLR. On the other hand, the least vulnerable segment, number 1, has a high slope (>4%), a topography higher than 10m, is uninhabited with no coastal infrastructure, and a very low hydraulic conductivity (0-12m/day). These attributes give it a very low vulnerability to SLR. (Segment count is from left to right).

Figure 5 shows a plot of the calculated $CV_{SLR}I$ for the Niger delta coastal segments. Analysing the results it is seen that, 42.6% of the coastline has 'very low' to 'low' vulnerability, 18.5 % has 'moderate' vulnerability, while 40.8% have 'high' to 'very high' vulnerability; which is shown in figure 6.

In figure 6, that the eastern end of the Niger delta (from Bonny to the southern end of Opobo (made up of six coastal segments: 49-54), is the longest stretch with very high vulnerability to SLR. **As shown in the case of segment 52, such areas with 'high' to 'very high' vulnerability are characterized by: 'very low' to 'low' slopes, 'very low' to 'low' topography, 'high' to 'very high' mean wave heights, unconfined aquifers, presence of coastal infrastructure and 'high' population density, etc. These variables represent physical coastal properties, human influence, and social properties. The presence of human influence variables like coastal infrastructure and high population density, increase the probability of damage to lives and property when a disaster occurs. The combination of these properties has made the coastal segments highly vulnerable to SLR.** The coastal segments classified as highly vulnerable to SLR will require mitigation measures to be applied against SLR.

The advantages of using a method such as $CV_{SLR}I$ is the fact that it **takes into account existing social structures (in terms of favourable places to live/ invest in infrastructure) and shows the level of vulnerability of choice areas. For example the ranking of segments 1 and 2 for physical variables (1-7 in tables 2) are similar but their vulnerabilities are very different (see table 5), since in the $CV_{SLR}I$ method human influence variables differentiate between the vulnerabilities of the two segments. While segment 1 has a 'very low' vulnerability, segment 2 has a 'high' vulnerability due to its high population density and presence of many settlements along the coast. If the CVI calculation was based on physical factors only, both segments will have similar vulnerability and segment 2 will be given a 'very low' vulnerability ranking (consequently, it will not be included in any adaptation plan). The $CV_{SLR}I$ however, requires a wide range of data collection for the physical, social, and human influence factors which might not be readily available. Moreover different variables might be available in countries within the same region, making comparison difficult. "**

Comment 3: However some definitions and delineation between vulnerability/susceptibility/resilience would be helpful for a better understanding of the methods used.

Authors' answer: The definition for vulnerability as used in this study is the one from page 5213, lines 3-15 of the discussion paper. The definition relates the vulnerability of an area with its susceptibility and resilience; which are further defined in lines 16-20 on page 5221. However if the reviewer finds these definitions inadequate, we will appreciate any advice and/ or references from the reviewer that can better explain the concepts and we will gladly improve the definitions, as long as they are pertaining the notions we have worked with.

Comment 4: Please check the numbers of the equations (Eq. 4 is numbered twice).

Authors' answer: Thank you for the correction, the equation numbering will be corrected in the final paper.

Comment 5: Strengths: the main strength of the CVI methodologies is that it allows the decision maker to identify the problematic areas and select adequate management strategies. It also helps to analyze why an area is vulnerable (exposure, susceptibility, resilience). Another advantage is that the indicators are flexible to adapt to changes in climate or development allowing for an indicator describing the study area as it is presently. Weakness: However, there are also a number of weaknesses presented here. The main weakness is that a system of indicators can never represent a complete image of the actual situation. The indicators could be inadequate for certain situations (not in this case study). Furthermore, when summarizing a situation in any number of indicators, information is always lost.

Authors' answer:: We thank the reviewer for highlighting the strengths of the methods used, and appreciate that we have the same view about the weaknesses of the CVI method. As stated by the reviewer, where there is no availability of indicators, the CVI method can provide inadequate results.

Table 5: Ranking per indicator and CVI results for the first four segments

SEGMENT NO	**1**	**2**	**3**	**4**	**52**	**54**
VARIABLE (FACTOR)			**RANKING**			
Topography (e)	1	1	2	1	4	2
Coastal slope (e)	1	1	4	4	4	5
Geomorphology	5	4	5	5	4	4
Relative sea-level rise rate (e)	5	5	5	5	5	5
Annual shoreline erosion rate (e)	5	5	5	5	4	4
Mean tide range (e)	4	4	4	4	3	3
Mean wave height. (e)	5	5	5	5	3	3
Population density(e)	1	4	4	4	5	5
Coastal infrastructure (e)	1	1	1	1	1	4
Hydraulic conductivity (e)	1	1	4	4	5	1
Proximity to coast(e)	1	4	1	4	5	5
Reduction in sediment supply (e)	5	5	5	5	5	5
Type of aquifer (e)	5	5	5	5	5	5
Population growth (s)	5	5	5	5	5	5
Groundwater consumption (s)	2	2	2	2	3	3
Emergency services (e)	1	1	3	3	1	5
Past experience (r)	5	5	5	5	5	5
Communication penetration (r)	1	1	4	4	1	5
Shelters (r)	1	1	1	1	1	1
CVIexposure	5.56	19.88	31.43	44.44	60.00	47.14
CVIsusceptibility	2.64	2.63	5.27	5.27	7.23	6.45
CVIresilience	0.56	0.56	1.94	1.94	0.56	2.8
CVIslr = $\frac{CV_E I * CV_S I}{CV_R I}$	**26.19**	**93.70**	**85.53**	**121**	**770**	**108.87**
Normalized result	**0.02**	**0.11**	**0.10**	**0.15**	**1.0**	**0.13**