Nat. Hazards Earth Syst. Sci. Discuss.,
doi:10.5194/nhess-2016-157-AC1, 2016

Natural Hazards and Earth System Sciences
Discussions
Open Access

Interactive comment on "An examination of land use impacts of sea level rise induced flooding" *by* Jie Song et al.

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Received and published: 4 October 2016

Dear Reviewer,

The authors are highly grateful for the insightful comments and suggestions. Based on the comments, the manuscript was revised and improved. The authors meticulously reviewed and proofread the manuscript to ensure that the revisions addressed every aspect of the comments. Below please find our detailed responses to the comments. Again, thank you very much for your time and efforts on reviewing our paper.

General comments:

1. The authors have addressed an important issue in Land Change Science by addressing multiple issues relevant to the field simultaneously. First, they employed a

CA model to understand historical parameters of land use change in the area of interest. Second, they used this information to explore future scenarios of generalized land use policy cross-dimensionally with different levels of SLR. The issue of managing SLR adaptation in low-lying areas is absolutely critical and so this research is of great urgency.

Response: We totally agree with the reviewer. Hurricane Katrina, Hurricane Sandy, and other disastrous coastal hazards have led to enormous economic losses and serious life consequences. These lessons have urged coastal communities to take actions to protect their residents from coastal hazards. Thus, the research on SLR adaptation is of great importance. Additionally, it is crucial to identify potentially vulnerable areas to SLR, and therefore local governments can efficiently allocate recourses to optimize the deployment of SLR adaptation strategies. This study was thus initiated in order to develop an integrated framework that connects urban dynamics and SLR related hazards.

2. Having said that, I do have some comments on the methods used to reach the conclusions cited at the end of this paper. First, the authors borrow from the techniques developed by Onsted and Roy Chowdhury (2014) but they missed one of the most important points of that paper: measuring urban growth over an entire zone is not an accurate way of understanding differential impacts over a heterogeneous landscape. The results of their work show that utilizing such a technique results in worse goodness of fit metrics than treating the landscape as homogeneous. Instead, the authors recommend using the AMLEG technique which helps to address distance decay effects that dilute the efficacy of measuring all urban growth in a large zone. I strongly suggest the authors take a look at this technique (in Onsted and Roy Chowdhury (2014)) as its employment will increase the accuracy of the E values in the E-1 scenario.

Response: Thank you for the comments. We acknowledge that urban growth over a large study area is heterogeneous. Therefore, we developed a new E3 excluded layer that was based on the AMLEG approach. Significant improvements have been made in terms of overall research framework, the methodology, results, and discussions. First, the new E3 excluded layer was incorporated into the new study framework (Figure 3 on Page 7). Second, a new section was added to the methodology part to illustrate the procedures by which the flooding-risk mitigation based the AMLEG was developed. In section 3.2.4, we will add "Most SLEUTH modelers apply the above-mentioned methods to develop excluded layers. However, such methods are deficient since they usually treat the whole study area homogeneously. Conversely, urban growth is more likely to involve heterogeneous changes across the study area. For instance, in coastal regions new residential developments largely extend from existing settlements that may only cover a small portion of the whole study region. Thus, Onsted and Chowdhury (2014) developed a procedure that corrects the growth rates in the AMLEG. The authors concluded that the AMLEG technique produced more accurate results than the other two methods: arbitrary guessing and the calculation based on the whole study area. Therefore, the AMLEG was applied based on the E1 scenario (flooding mitigation). The SLEUTH was run in the prediction mode for 100 Monte Carlo times for the period of 1995 to 2013. All five growth coefficients were set as 100, and the cells with an urbanization probability of 50% or more were considered in the AMELG, as shown in Figure 7" [Page 12, Line 1 through Page 13, Line 5].

In the section of results and discussions, we made the following improvements.

1) Page 16, Line 30 through Page 17, Line 5: The quantity of urban growth under the E3 excluded layer was discussed and compared with the other policy scenarios.

2) Page 17, Line 8 through Line 12: Urban growth up to 2080 under the E3 scenario was illustrated in Figure 10 and discussed in the text.

3) Page 19, Line 3 through Page 20, Line 4: The AMLEG effects on urban exposure to sea level rise induced flooding were shown in Tables 8-9 and Figure 12 and analyzed in the discussions.

3. Second, the authors made no attempt to scientifically derive the differences amongst

the land use zoning categories in their construction of E2 as they did for E1. Instead, they just guessed because others have done so. However, other results from Onsted and Roy Chowdhury (2014) suggest that guessing results in poor accuracy as well, or at least worse than treating the entire area as homogeneous.

Response: The authors appreciate the comments. This is a limitation of our work. Although we tried to cite reliable sources to develop adequately scientific estimates for the excluded values of E2, we fail to point out potential bias due to the experience-based method in the original manuscript. The E2 layer should be recreated using historical data and more robust techniques such as the AMLEG, but we had difficulty collecting historical zoning maps corresponding to the past land cover maps. Therefore, we will highlight and discuss the methodological deficiencies by making the following improvement in the revised manuscript.

Page 22, Line 19 through Line 22: we will add "Third, urban growth predictions may be biased if modelers fail to justify the values in excluded layers. This study determined the excluded values of E2 scenario according to future land use plans and suggestions from other studies (e.g., Akin et al., 2014). Although the lack of historical zoning information forced us to make this assumption, the predictions under the E2 scenario may become problematic".

4. Third, best practice usually discourages forecasting further into the future than you have calibrated in the past. The authors have data from 1974 to 2013, which is 39 years of data. But they use this to forecast 67 years into the future. Please see the figure from Goldstein et al. (2014). Goldstein, N.C., J.T. Candau, and K.C. Clarke. 2004. "Approaches to simulating the "March of Bricks And Mortar"". Computers, Environment and Urban Systems 28:125-147.

Response: Thank you for the insightful comments. The authors totally agree that urban growth predictions should not exceed the time range of calibration. In initial experiments, we considered a short time frame but found that sea level rise impact was extremely limited. Thus, the authors used a longer forecasting time range to make significant the sea level rise consequences. In addition, some studies may suggest that scenario-based predictions may choose an aggressive extrapolation option to show any emerging patterns, while the interpretation of results should be very careful. This can be seen in a recent report that forecasts future urban developments in 2070 for the whole Florida (Mapping Florida's Future – Alternative Patterns of Development in 2070, retrieved through: http://1000friendsofflorida.org/florida2070/wp-content/uploads/2016/09/florida2070technicalreportfinal.pdf). However, the authors made the following discussions regarding the issues associated with extrapolation.

Page 22, Line 30 through Page 23, Line 4: we will add "Given these uncertainties, therefore, the simulation results should be interpreted with extreme carefulness and objectivity. In addition, the extrapolation of future urban growth beyond the calibration range can be questionable and generate uncertain results (Goldstein, Candau, & Clarke, 2004). Modelers ought to make a trade-off between urban predictions and the forecasts of climate change related hazards. Climate change is slow going, but urbanization may be rapid in populated coastal regions. For instance, SLR may become significant only after an adequate time frame that probably exceeds the time period of historical urban data. Such coupled analyses should aim at identifying the general impacts of climate change on prospective urbanization, rather than replicating past patterns of urban development".

5. Fourth, the future scenario results are less emergent from interacting and hard to predict factors than they were engineered by the authors to fit a priori expectations. For example, a sprawl scenario was designed by tweaking the model's growth parameters until sprawl was achieved. However, it is important to reflect upon the utility of such scenarios for understanding the nature of urban growth in the area as well as how it can help us improve our modeling methods. For example, from a policy maker point of view, what suite of policies will lead to such a sprawl scenario? What suite of policies will lead to a compact growth scenario? The sprawl and compact growth scenarios are

implicit in the sense that they suggest "if a series of circumstances happen that result in sprawl, this is what sprawl would look like". However, do we need a model to tell us what future sprawl will look like if we already decide what that future is? The more the outcome is controlled the less predictive quality the model has.

Response: The authors are very grateful for the comments. Many historical urban growth cases have witnessed urban sprawl and compact development. These urban forms are two of the more representative urban growth patterns than others. So we choose them to examine the sea level rise impacts on possible urban change scenarios. In fact, scenario-based predictions were adopted by numerous similar studies (see, for example, Refiee et al. (2009), Zheng et al. (2015), and Sakieh et al. (2015)). We admit that more model controls mean less flexibility, so we used the historical growth pattern as a reference. Additionally, we highly agree with the referee that it is crucial to identify the policy implications of various growth patterns, which is absent in many simulation papers. Thus, we reorganized the section of policy implications by following a logically connected flow of the text. First, we discussed how urban forms were exposed to sea level rise and which urban form appeared less vulnerable to climate change related hazards. Following this, we expanded the discussions by talking about other dimensions of urban forms such as their influence on social-ecological welfare and different policies leading to different urban patterns. Lastly, we narrowed down our discussions by proposing general policy frameworks that promote both societal prosperity and hazard mitigation. In summary, in the new manuscript, we made the following changes.

Page 23, Line 16 through Line 29: we reviewed policies leading to urban sprawl. "Population and economic growth largely drive urban growth. Yet, policies behind such growth should also be investigated since land use plans and economic strategies represent developmental blueprints. Thus, it is beneficial to reflect upon different policies contributing to distinct urban growth patterns: urban sprawl and compact growth. Urban sprawl is characterized by unplanned and scattered developments in suburban areas. Uncoordinated growth in the city edge has been suggested to be associated with multidimensional factors regarding economic incentives, housing development plans, and transportation policies (De Vos & Witlox, 2013; Lopez & Hynes, 2003; Yue, Zhang, & Liu, 2016). Economic incentive packages launched by the central government have contributed to urban sprawl in the developing world. For instance, China took economic reform in the 1970s by opening up land markets and commercializing housing units. This economic stimulus gave rise to many sprawling mega-cities such as Beijing, Shanghai, and Chengdu. In Europe and North America, micro-economic theories may explain urban sprawl. Households begin to relocate to the suburbs when the land prices in city centers become prohibitively high. Their relocation decisions are further strengthened by housing and land development policies. Developers promote low-density communities in the city periphery. Local governments help to build large retail centers to accommodate the increased demand. Motorization policies and low fuel costs result in automobile-oriented cities. Even public transit policies aggravate outward city growth by charging long-distance commuters less than riders for short distances (De Vos & Witlox, 2013)".

Page 23, Line 29 through Page 24, Line 6: The policies promoting compact development were reviewed. "As urban sprawl increasingly threatens public health, social equity, and the built environments, people start to develop different urban containment policies. There are primarily two forms of containment policies that were adopted in the US. The State law in Oregon and Washington requires that local land-use plans should clearly define an urban growth boundary. In other states such as Florida and Maryland, governments develop urban service limits, public facilities ordinances, and other policies to promote compact urban forms (Aytur, Rodriguez, Evenson, & Catellier, 2008). However, the effects of urban containment policies have been hotly debated. For example, not all urban growth boundaries significantly affect housing markets and urbanization paces (Dempsey & Plantinga, 2013). Thus, De Vos and Witlox (2013) suggest the integration of spatial planning policies, mobility policies, and road pricing. Spatial planning can strictly limit new developments outside urban areas. The de-

velopment of Transit-Oriented Development benefits nurturing high-density and mixed land-use neighborhoods. In addition, road pricing increases long-distance travel costs, thereby curtailing urban sprawl".

6. I suggest that authors, at most, redo the aspects of the methods described above. However, at the least, the issues I mention above should be discussed in the article as possible deficiencies in the current methodology.

Response: Thank you for the suggestions. We have spent great efforts on redoing the crucial aspects regarding the current methodology. As stated in the response to the second comment, a new E3 excluded layer was created based on the AMLEG technique, and some parts of the simulation were run again to incorporate this change. Accordingly, substantial changes were made in terms of the methodology, the visualization of results, and discussions. However, we fail to redo a few methodological aspects raised by the referee due to data limitations. We did highlight and discuss these method limitations in the discussion section [see Page 22, Line 1 through Page 24, Line 17].

7. The strongest aspect of this work is the integration of SLR scenarios vis-à-vis future urban growth scenarios. This line of inquiry is absolutely critical for coastal resilience and thus the authors should be applauded for the great importance this kind of research has on the sustainability of our worldwide coastal civilizations.

Response: We are grateful for the referee's applause. We hope that the research could be a small yet important effort in the coastal resilience science. Informative decision support tools can greatly benefit coastal communities and mitigate the economic and life consequences of coastal hazards.

Specific comments:

1. Page 4, Lines 25 thru 30: The impervious surface percentages for the various zoning categories mentioned are incorrect (I checked). The authors need to revise this

accordingly.

Response: The authors apologize for the confusion. We carefully read the source document again and rephrased the explanations to make clear the impervious surface percentages [see Page 5, Line 19 through Page 6, Line 6].

2. Page 6, Line 12: This should read "percentage slope" instead of percentage rise since percent slope is rise over run.

Response: Thank you for pointing out the accurate terminology. The text was then corrected according to this comment [Page 8, Line 3].

3. Page 10, Line 14: Increased SST does not cause higher pressure over the ocean, but lower pressure. The magnitude of a hurricane is often directly related to how LOW the pressure in the eye is, thus Lower is stronger. The authors seem to have this reversed.

Response: Thank you for this comment. The authors carefully went through the original citation and found that we had some misunderstanding on this phenomenon. Thus, the text was revised based on this comment [Page 15, Line 9].

4. Page 11, Lines 12 thru 18: The methods the authors list (differences of 25, etc.) does not match what they actually have listed in Table 5.

Response: Thank you for the correction. We found the typo in Table 5 and revised it accordingly [Page 16, Line 15].

5. Page 14, Line 14: The authors seem to suggest that sprawl leads to less vulnerability in all coastal areas and thus policy makers must choose as a tradeoff between sprawl with all of its negative environmental consequences or flooding. However, the most important factor is not necessarily proximity to the coast but, rather, simple elevation. Thus Panama City is not necessarily representative of the topographical constraints and opportunities in all coastal areas.

Response: We appreciate the comment. The previous statement suffered from the inappropriate generalization of the exposure of different urban forms to sea level rise. Thus, we rephrased the statement and the conclusion about urban vulnerability. We will add: "Yet, this might not be true in flat coastal areas from the perspective of hazard mitigation [Page 23, Line 7] ... however, such conclusions are made only based on our case study area where the elevation is low and change insignificantly[Page 23, Line 11]".

6. Page 14, Lines 28 – 29: As Florida sits on porous limestone a seawall will not keep out SLR since the ocean will just come up underneath on the other side.

Response: Thank you for the comments. The following text was added to include this information suggested by the referee. "In the long term, adaptation plans ought to consider other SLR aspects such as groundwater pollution and saltwater intrusion beneath protective structures [Page 24, Line 15]".

7. Figure 1: There are three maps at three different scales but only one scale bar is used. Each frame should have its own scale bar.

Response: Thank you for the comments. The figure was improved with each map having its own scale bar. The enhanced figure could be found on page 4.

8. Figure 6: Though technically an Excluded Layer can be portrayed however one wants in the actual publication it is confusing to see the actual Excluded Layer in grayscale but portraying the opposite grayscale values of their E scores. Thus the ocean should be 100 or over, but instead is represented as 0, etc. It could be helpful to those in the SLEUTH community if the authors showed the grayscale Gif Excluded layers exactly as they are.

Response: We appreciate the comments. The authors apologize for such confusions. Thus, in our new figures, the water bodies were not assigned any excluded values. We hope this improvement helps to clearly depict the excluded layers [see Figure 4 on

Page 9, Figure 5 and 6 on Page 11, and Figure 8 on Page 13].

9. Figure 9A, 10A, and 11 A: The bounding boxes should be removed as they serve no purpose. They should instead be used in Figure 12 as it appears that is where they correspond.

Response: We removed the bounding boxes according to the referee's suggestion. In addition, these three figures were combined to reduce the total number of figures [Figure 10 on Page 18].

10. Figure 13: The dark blue color appearing in the maps of this Figure does not appear in the legend. I am assuming it is urbanized land that is also flooded. However, guesswork should not be required by the reader.

Response: Thank you for the comment. A complete legend was added in Figure 12. In addition, the authors greatly enhanced the readability and appearance of figures by increasing figure resolution, enlarging legends and texts, and redesigning the layout [see Figure 2, Figure 4, Figure 7, Figure 9, Figure 10, and Figure 12].

11. Technical: There are numerous spelling issues, missing articles, etc. throughout the manuscript. For example, "Talbe 4 About here". Or poses "unnecessarily" risk instead of poses "unnecessary" risk in the abstract. Another pass of proofreading is recommended.

Response: The authors highly apologize for grammatical mistakes. We have carefully proofread the whole manuscript to exclude language issues as much as possible. Special attention has been given to misspelled words and article issues. Furthermore, we inserted figures and tables into the main text and rearrange the overall structure in the new manuscript. Readers can then relate the information with illustrations and numbers more easily.

Please also note the supplement to this comment:

http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2016-157/nhess-2016-157-AC1-supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2016-157, 2016.