

Dear Editor and Reviewers, NHESS,

First of all, we deeply appreciate the editor and reviewers' efforts to evaluate our manuscript, and also must thank them for the fact that they spent their precious time in conducting this reviewing process. The authors wish to express their gratitude for a number of constructive comments and advice given regarding the original manuscript, which much assisted the authors in its revision. Please find below a detailed reply to all reviewers' comments.

Kind Regards,

Hiroshi Takagi
Tokyo Institute of Technology

Reply to the comments:

In blue: reviewers' comments

In red: authors' reply

Reviewer #2

General comments

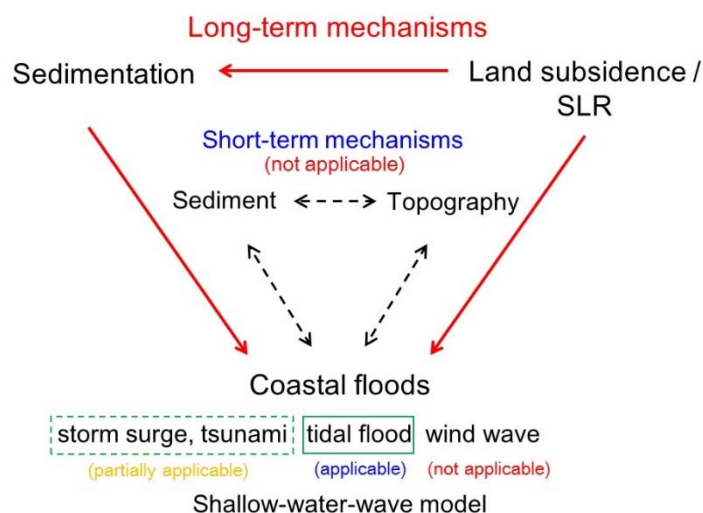
The paper addresses a topical theme and provides important insight for the design of mangrove restoration. Mangrove restoration has sparked in popularity in an attempt to make up for their alarming global loss and because the features they offer for coastal protection is particularly interesting for adaptation and risk reduction. However, successful restoration cases have been, in general, very scarce. Rates of successes have been characteristically low, in part due to lack of adequate designs for initial protection of seedlings and embankments. This paper specifically addresses the latter point and provides useful information for restoration on the ground. I suggest its publication after addressing a few key points.

We thank the reviewer for the great number of very productive comments and suggestions, which would enable us to significantly improve our manuscript.

First, the paper focuses on tide attenuation to show the potential of mangroves to reduce coastal flooding. However, it is not clear from the onset of the paper that 'mitigation of coastal floods' only refers to 'ocean tides'. Furthermore, if it is unclear if this term

refers only to astronomical tides throughout the paper since other drivers of flooding are cited and discussed. The paper refers to waves, storm surges, tides and tsunamis. While wind waves are short waves; surges, tsunamis and (astronomical) tides are long-waves that behave differently to each other. This point must be clarified and the author should provide a clear definition of what tidal propagation refers to within the scope of the paper. In the same regard, scope and goal of the paper could be better framed in Figure 1 too (see specific comments below).

Sorry for the insufficient explanation on the types of coastal flood. Although astronomical tides are only discussed in this paper, mangrove is expected to mitigate storm surges, tsunamis, and high waves in addition to tides. Due to the theoretical limitation of shallow-water-wave model, tidal flood is mainly addressed. The relative depth, which is defined as the water depth divided by the wave length, is commonly used to classify the types of waves. If the relative depth is smaller than 1/20, the given wave can be considered as a shallow-water wave. Given this criteria, not only tides but also storm surges and tsunamis are considered shallow-water waves. Nevertheless, abrupt changes in the water levels may also appear during tsunamis or storm surges as a form of bore or soliton fission. Because mangrove mainly inhabits very shallow-depth regions, these strong non-linear characteristics will be particularly pronounced. The depth-averaged velocity assumption adopted in the equations may not be applicable if such a mechanism occurs. On the other hand, it is obvious that ordinal wind waves of periods less than 20 s are by no means shallow-water waves. Therefore, it is not appropriate to apply the model to wind waves. In this way, the scope and the applicability of the proposed model will be clarified in the revised manuscript.



New figure to be inserted in the revised manuscript: Scope and the applicability of the proposed model. Long and short-term mechanisms could both cause morphology changes of a mangrove embankment. However, only the long-term mechanisms were taken into consideration in this study. The shallow-water wave model adopted here can reproduce the propagation of not only tides but also storm surges and tsunamis over the embankment. However, the latter mechanisms may not be always reproduced.

Similarly, it is confusing how deterministic astronomical tides are relevant in the context of EcoDRR and catastrophic coastal flooding. Tides are one of the factors of extreme sea levels but they rarely are the main driver in extreme flooding events. It is assumed that tide propagation is used here as way to measure flood reduction more broadly (storm surges?) and given that the equation is the same for both types of long waves, but this requires further clarification.

On the same token, it should be clarified that tide attenuation is only tested for specific tide characteristics (1 amplitude and 1 tide period in Figure 4), for different geometries of the embankment. While the analyses focuses on highlighting the effects on the different embankment geometries, the discussion should merit some acknowledgement of the fact that flood events with different characteristics (amplitude and celerity-duration) would behave differently.

Thank you for pointing these out. The present study focused on the most unfavorable wave type in terms of the flood mitigation with mangrove forest. The longer the wave period, the smaller the wave attenuates.

Therefore, the authors believe that investigating the diurnal tide is ideal for observing the fundamental function of the mangrove embankment system. The tidal damping for semi-diurnal tidal components, which are half the periods of the diurnal tides, appears to be more remarkable compared to the diurnal tide, when their amplitudes are the same. From the view point of Eco-DRR, it should be noted that the effectiveness of the mangrove embankment system will be automatically assured for tsunamis, storm surges, and high waves if it is effective against astronomical tides.

Also, some reorganization and text improvement should help to facilitate the reading and an overall understanding of the paper main contributions. Some suggestions are included in the specific comments.

Finally, it should be clarified (maybe in discussion) that the paper refers only to tide attenuation and the consolidation of the embankment over time but other factors, such as the diversity of species, are also critical for flood reduction and good ecological

performance. Diverse species increase friction (manning coefficient) in the mangrove forests and reduces flooding but are also a key component to becoming functional ecosystems, in the context of Eco-DRR. Many restoration cases in the past have failed to recognize the species diversity as a clear factor in restoring mangrove forests for flood protection.

Thank you so much for giving this great comment. We agree the importance of the role of diversified species in reducing floods. Some statement such as below will be added in “4. Discussion” of the revised manuscript.

Diversity of species: Although beyond the scope of this study, the diversity of mangrove species planted in the embankment should also be critical for creating functional and balanced ecosystems, which eventually contribute to flood mitigation by increasing the bottom friction in the mangrove forests. The magnitude of response to nutrients varies across mangrove species. Thus, within the intertidal zone, different species prefer different elevations, salinities and inundation frequencies.

Specific comments

Page 2 line 8-10 – Phrase unclear. line 10-12 – rephrase. Maybe: mangroves provide key ecosystem services such as : : : Also, explain ecological resilience in this context.

The corrections will be made in the revised manuscript.

line 6. Move ‘salt marshes have also : : :’ after ‘vegetation decreases: : :’

The corrections will be made in the revised manuscript.

line 21. Not all urban areas are suffering subsidence and sea level rise. Clarify and express better that: ‘mangroves can help reduce risk in urban areas under threat from sea level rise and subsidence’

The corrections will be made in the revised manuscript.

line 29-31. See (Sasmito et al. 2015) for a discussion on mangroves and sea level rise. Page 3 Line 3 onwards. Clarify and define tides, surges and tsunamis. Line 13. Remove or describe sections at the end of the introduction Line 25-27. How is it affected by erosion of the waterfront? Clarify that erosion of the waterfront (for example from wave action) is not considered in the model.

The corrections will be made in the revised manuscript.

Line 29 onwards. While figure 1 describes the overall approach and design of the numerical experiment, the text in section 2.1 is described as conclusions rather than methods or hypothesis that the paper will test. It is suggested to rewrite this paragraph to better express what scenarios the experiment will address and compare.

The correction will be made in the revised manuscript.

Line 6. Describe differences between surges, tides and tsunamis and that only tides will be used in the paper.

The details on what type of coastal flood can be dealt with the proposed model will be clarified in the revised manuscript.

Page 5. Where is u_e (eq 5) used in eq 6 and 7?

Equation 8 will be modified to explicitly indicate the parameter:

$$U(T) = \int_0^1 \left(1 - \frac{u_e}{q_s}\right) dZ = 1 - \sum_{n=0}^{\infty} \frac{2}{a_n^2} \exp(-a_n^2 T) \quad (8)$$

Page 5 and 6. It is unclear where sediment deposition (later analyzed in the paper) appears in these equations. Is this through a linear sediment accretion rate (section 2.4)?

The details on this regard will be clarified in the revised manuscript.

Line 31. MSL : Mean Sea Level

The correction will be made in the revised manuscript.

Page 7. Section 2.5. Format or describe the case study.

Line 30. Consider removing.

The correction will be made in the revised manuscript.

Page 8. 1st paragraph. Only by soil consolidation?

Line 12. Because mangroves trap sediment: : : Line 24. Tide attenuation scenario is unclear. Line 26. Reduce the tidal energy? Unclear.

The correction will be made in the revised manuscript.

Page 9. Line 1-3. Outline better the 3 factors: plants height, water depth, embankment width and depth.

The correction will be made in the revised manuscript.

Line 4. Define vegetation growth ratios. This variable is also used in subsequent figures but is unclear what it refers to.

The correction will be made in the revised manuscript. The present model defines the vegetation growth ratio to represent to what degree the mangrove plant grows. The ratio is assumed to linearly increase from 0% at the beginning and reaches 100% after 10 years.

Line 12-15. This paragraph is discussion material.

The paragraph will be moved to another section which would fit with this context.

Paragraph in line 20. How tidal amplitude influences the analysis? It is not defined in the paper that tide attenuation is only tested for a specific tidal amplitude and tide period. However, flood attenuation would depend on the wave amplitude and celerity (i.e.

period) in relation to the geometry of the embankment (depth and width), as seen in equations. In other words, for the same tide properties, different embankment geometries provide different attenuation factors, but for the same embankments, different tides would exhibit different behavior too. If sensitivity of the results to tides (and other flood events) is not explored, it should be properly acknowledged and described.

We consider that investigating the diurnal tide is sufficient for observing the fundamental function of the mangrove embankment system, which simultaneously experiences multiple external influences such as SLR, subsidence, and sediment accretion. Nevertheless, the discussion regarding different wave characteristics will be of great benefit to readers. Instead of giving additional simulated results for different tidal conditions, this appendix introduces some relevant mathematical expressions to discuss how a tide can behave differently under different conditions in terms of wave and platform geometries.

Line 30. The results presented confirm : : :

Page 10. Line 2. Use SLR consistently throughout Line 3. Tide amplitude and period too?

Line 19. Both potential and negative effects: Line 19. Paragraph also discussed in results. Consider consolidating.

The correction will be made in the revised manuscript.

Line 29. Erosion of embankments usually occurs from wave action at the forest front when the area is not properly sheltered from it.

We agree. The accelerated erosion at the embankment front will be stated in the revised manuscript.

Line 30. Diversity of species in the forest should also be consider to provide better frictional drag and functional ecological performance.

We agree. The diversity of species and its role in mitigating flood will be stated in the revised manuscript.

Page 11. Define and use MSL for mean sea level consistently throughout Line 4. Use static rather than stable. Line 6. Rewrite. For example: For example, climate patterns such as El Niño Southern Oscillation can increase sea level and these variations have been shown to larger than historic trends in sea level rise (e.g. Losada et al. 2013).

The correction will be made in the revised manuscript. Also, the suggested article will be cited to discuss the potential impact of ENSO.

The authors may consider adding a final discussion point on how these results could inform flood attenuation for other events that are not ocean tides.

Although this study focused on oceanic tides, the proposed methodology could also be useful to investigate the effectiveness of mangrove platforms against storm surges and tsunamis. In the revised manuscript, we will put more clarifications on the applicability of the model to the other coastal floods and also discuss limitations with that.

Line 16. Keep the mangrove surface level up with : : :

The correction will be made in the revised manuscript.

Line 20. These values of attenuation are specific to the tide amplitude and period. Technical comments on Figures Figure 1. It is confusing that ocean tides are here related to catastrophic flooding on urban areas (e.g. panel a). The sketch and text in the corresponding section should be more clear on what the sketches represent and what is the particular scope of the paper.

The scope of the paper will be more clarified by stating the type of coastal disasters concerned in the revised manuscript. Also, Figure 1 will be replaced by the revised figure, as shown below, in order not to give a false impression of astronomical tidal floods.

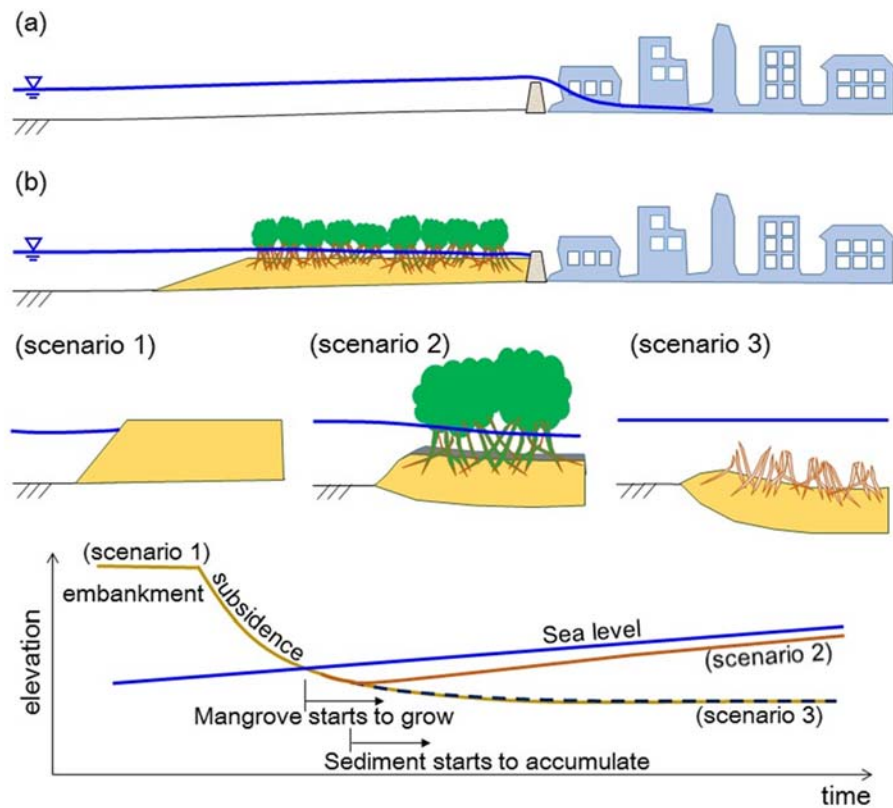


Figure 3. add the sedimentation rate. 1 cm/yr?

The correction will be made in the revised manuscript.

Figure 4. Define “vegetation growth rates” and “growth ratio”. Do they represent the same variable?

The correction will be made in the revised manuscript.

Figure 5. The 3D perspective is confusing. Suggestion: 3 panels, one for each water depth.

Indeed, there is some difficulty to realize the figure with three parameters. However, we consider it will also be useful to quickly see those interactions among the factors simultaneously. Thus, we would like to keep this figure as it was.