Response to anonymous reviewer / RC2

We sincerely thank the anonymous reviewer for thoughtful feedback on this manuscript, including both broad topical suggestions and grammatical or word choice suggestions. We especially appreciate these reviews considering this paper presents the first iteration of a new research tool.

A recurring misconception with the review is that HazMapper is a semi-automated method and that we did not provide quantifiable data needed to assess the rigor of a semi-automated approach in identifying natural hazard features. This initial release of the HazMapper application does not semi-automate the identification of natural hazard features. Identification of natural hazard features and assessment of the signal-to-noise ratio in the rdNDVI output is incumbent upon the user. At present, we believe many in the natural hazards research, prevention, and outreach communities will find HazMapper to be a useful utility that will assist in their exploration and characterization of many different types of natural hazard features. Our hope is that future iterations of the tool will focus on individual hazard types (e.g., mass wasting; wildfires; tornadoes) where further analysis and semi-automation will be employed.

Color legend
RC1 - black
Author response - blue

Topical comments
The authors present a simple interface to Google Earth Engine that allows the user to map the impact of natural disasters using changes in vegetation seen in satellite images. Specifically, the relative difference in Normalized Difference Vegetation Index (rdNDVI) of Ambrose et al (2019) is calculated from Sentinel and Landsat images acquired before and after the natural disaster, and the resulting map of rdNDVI is displayed in such a way to highlight the vegetation changes. The interface then provides a tool to digitize these changes and export the resulting shape, along with the original images, to various formats. The impact of opaque atmospheric clouds is mitigated by the use of greenest pixel composites, which mosaic images over a given time period, selecting for each pixel the greenest values from the images in that period. The utility of this approach is shown with 5 case studies, two of which are validated using published data. I have been able to follow the procedure outlined in the flow chart in figure 2 and confirm that the functionality works as presented. The novelty in this paper is the combination of the pre existing methods of rdNDVI and greenest pixel compositing, along with the Google Earth Engine service, to map hazard related vegetation changes, as well as a simplified user interface to make this accessible to the public. The authors are to be commended for trying to span the gap

between the world of cloud computing and big data, which allow very large satellite datasets to be processed rapidly in response to a crisis, and government agencies and the general public, who could gainfully interact with the data, but may not have the expertise to engage with it through the Google Earth Engine directly. The web interface is streamlined and easy to use, and the rdNDVI technique appears to work well in the case studies, although it would be nice to see more ground truthing, or at least some kind of verification for the examples where there is none. I believe HazMapper has the potential to be very useful in the future and the authors have succeeded in producing a useful tool.

Response:
Thank you for the compliments on the web interface and thank you for testing HazMapper.

The change detection method presented is entirely based on vegetation changes. This is not mentioned in the title and abstract, so the scope of the paper is really quite a bit smaller than a cursory glance would imply.

Response:
We will add language in the abstract and manuscript to clarify this point.

I'm not sure the website succeeds in making natural hazard impact assessment completely open to non-experts. It seems you still need to know something about green-pixel compositing and why there might still be 'holes' in the images that will then propagate into strange features in the rdNDVI images, as well as what rdNDVI is measuring and how vegetation regrowth might affect it. I don't think rdNDVI can simply be used as a naive index of change that non expert use of the system implies. I do think this can be remedied by adding a tutorial mode that walks you through the case studies, pointing out what it all means and where the method fails. There are many JavaScript libraries that make this painless to implement, such as driver.js

Response:
Driver.js is an outstanding suggestion! We will explore that for http://hazmapper.org/learn. We have also initiated work with a large European university to develop a landslide mapping module with them this autumn using HazMapper.

Apart from Figure 1, the figures that present the results of using HazMapper in various settings seem to have been made in ArcMap using data exported from HazMapper – this gives a somewhat misleading presentation of what the website actually does. In particular, it does not seem to be possible to reproduce the style of presentation in figure 3, which looks like thresholded rdNDVI over greenest pixels in HazMapper. I think either this thresholding ability needs to be added to HazMapper (which shouldn't be

hard) or the figures need to be changed to screenshots from HazMapper to reflect the actual user experience.

Response:
We have tested some user-driven color ramps in HazMapper and will implement in the future, but for the first iteration, believe a generic -50 to +50% change in rdNDVI red to blue color ramp best suits most users. This color ramp saturates at -50 and +50%. Values greater than this will have the same color at a 50% decrease or gain in rdNDVI. The download functionality of HazMapper is intended for users to download data for use in other geographic information systems software platforms (e.g., ArcGIS, QGIS, GRASS GIS, etc.,). We have posted our ArcGIS Pro compatible symbology files used to render the data presented in the figures on our website: https://hazmapper.org/resources-faq/

Additionally, a new figure 8 (included at the end of this document) to address a comment from RC1 about the utility of Landsat 7 data and HazMapper because of it's well known scan-line error issues will include the default map and color ramp layout that a user would experience at the HazMapper user interface.

Stylistically, the paper can be quite "wordy" with redundant words within sentences and the same concept being explained repeatedly in successive sentences and in successive sections of the paper. I feel the whole paper could do with being edited for brevity – I've highlighted some examples in the detailed comments below

Response:
Thank you for this comment. We agree with the assessment and will remove repetitive portions of the text.

The paper is quite "jumbled up". Advantages of Google Earth Engine are mixed in with the advantages of HazMapper, proven applications in the case studies are mixed in with proposals for future work, sentences extolling the virtues of HazMapper that read a bit like ad copy are present, some parts seem more like a research proposal. It's not always clear what's novel, what's been done before, and what is being proposed for the future. All of these components have their place in a paper (except the ad copy!), but they need to be separated out. I understand presenting a new tool like this departs from the traditional structure of a research paper, but I think the solution is to treat the case studies more like a results section, and have a traditional discussion section that assesses the results, and an extended conclusion section in which all the consideration for future work can be placed.

Response:

We will move the content of Chapter 3 Google Earth Engine vs. Traditional GIS environments into Chapters 1 and 2. This is consistent with a similar comment from RC1 and is well received. We will reduce "ad copy". We will include a Discussion section.

It seems to me that only making HazMapper available to the reviewers during submission to an open review journal is a missed opportunity to get feedback from a wider base of potential users. If the purpose of the paper is partly to advertise for potential users and contributors (as the current abstract implies), having it open at the review stage would seem like a good idea.

Response:
We have included several peers in the HazMapper Reviewers Google Group and they have been user-testing the application on various projects - academic research, applied emergency management work, and academic instruction. Coupled with this peer-review, our intent was to gather feedback from established professionals and researchers prior to a public release.

The source code should have been made available to the reviewers. The text also does not explicitly mention what licence the code will be released under – this should be included.
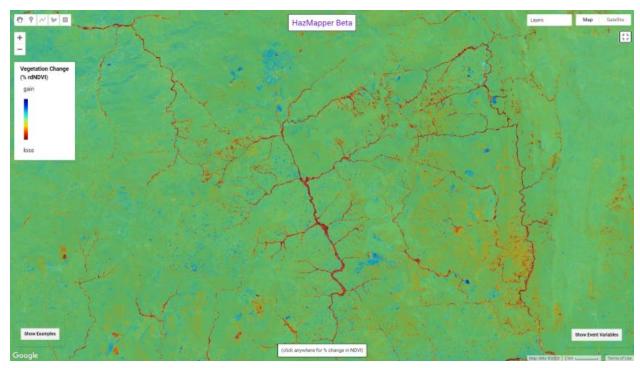
Response:
If the reviewers would like a copy of the source code, please let us know and we are happy to send it. License information for the source code will be included in the revised version of the manuscript.

The web interface could also be improved with an rdNDVI color bar and distance / area measurement tools, if possible

Response:
We have implemented a rdNDVI color bar - you will see this if you log in to HazMapper again (screenshot below). Thank you for the suggestion. Distance/area measurement tools are a bit harder to implement and we have added to our app-improvements suggestion list. For now, users can use the default scale bar (lower right) to estimate distances. Of course, by downloading data or digitizing and downloading features, further measurements can be made.

Example of new rdNDVI color bar, Mass Wasting induced by Cyclone Idai, March 2019, Zimbabwe/Mozambique border region

The website can be quite slow, and it is not always immediately obvious that the little bars in the layers button show the loading time. Also. sometimes the little loading bars indicate loading is complete, and yet downloads are not available. If there is extra "loading time" required in the background after the images are displayed but before they are available for download, this should be indicated to the user in some way.

Response:
You have described the exact behavior of trying to analyze too large of an area. Even Google Earth Engine has limitations, unfortunately. A good example is the 2019 Australia brush fires, which are difficult to analyze because doing so requires processing 10m (Sentinel-2) or 30m (Landsat) data at the continental scale.

If you have no download link appearing, you are trying to download too large of an area. Google Earth Engine currently limits downloads/exports to ≤32MB. We will describe this limitation in the text and add a warning message to the HazMapper interface to indicate such. We will continue to monitor the development of Google Earth Engine for increases to this file-size limit. Additionally, we are exploring ways to export data to a Google Drive if desired, which increases these download limits but also decreases accessibility to the application.

<u>Grammatical and technical suggestions such as word changes or further explanations required</u>

Line 1: "rapid repeat-cycles" here the words "repeat" and "cycle" are effectively saying the same thing, and don't tell you what is being repeated. I would change to "rapid image acquisition cycles".

Response:
We will remove this language from line 1 as suggested, but have left it elsewhere in the manuscript. The term "repeat cycle" is consistent with the remote sensing literature and the agencies responsible for launching and maintaining the main satellites used in HazMapper
ESA: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/sentinel-2
USGS:
https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0

Line 7: "HazMapper is openly available to the public" repeats the claim of line 4. It only needs to be said once in the abstract

Response:
We will remove the 2nd occurrence, thank you for the suggestion.

Line 9: "It is the intent of the authors ..." this reads like an advertisement or community announcement more suitable for a conference or email list than the abstract of a research paper. I would remove it. And if the intent is to advertise for users during an open review, the software probably ought to be open at the time of review. Limiting access to the web page until after the review is complete seems like a missed opportunity. Plus the source code itself really should be available to the reviewers.

Response:
We apologize for the misinterpretation of this statement and will remove it from the manuscript.

We have included several peers in the HazMapper Reviewers Google Group and they have been user-testing the application on various projects - academic research, applied emergency management work, and academic instruction. Coupled with this peer-review, our intent was to gather feedback from established professionals and researchers prior to a public release.

Regarding the source code availability, please see our response above to a similar comment.

Line 14: "developed : : : undeveloped" this distinction doesn't seem to be pertinent to the following discussion, I would remove.

Response:
We will remove this distinction from the manuscript.

Line 20: Again, not sure how this sentence is pertinent to the following discussion – this seems to be a point about a spatial scale below which natural disasters don't leave a lasting mark in vegetated landscapes resulting in incomplete historical records, but this point doesn't seem to be pursued? The following sentence seems to be saying that organizations are looking for evidence of these events, despite them leaving "no readily observable field evidence" in most instances, which doesn't make a lot of sense. I would rephrase this

Response:
Field evidence of vegetation disturbance from natural disaster events is ephemeral - in humid environments, vegetation grows back rapidly. Using a time-series of satellite data helps to look back in time even after vegetation has regrown, which is something we cannot do with fieldwork alone. We will modify the manuscript to clarify this point. Thank you for the suggestion.

Line 23: "field work is inefficient" compared to what? Maybe change to "inefficient compared to remote sensing methods" or something like this.

Response:
That is correct, compared to the remote sensing methods. We will modify the manuscript to clarify this.

Line 23: "provides a single time-stamp" - perhaps change to "snapshot in time", or some other wording – I think one can say data is timestamped, but I'm not sure it makes sense to say that a timestamp is provided, unless you are referring to a digital (or physical) text string that gives the time and date that is then attached to a bit of data?

Response:
We will modify the manuscript to remove "time-stamp".

Line 25: "The advent of rapid-repeat cycle satellite datasets : : :. has revolutionized" ! maybe change to just "revolutionized", or cut entirely. "has revolutionized" implies a recent or ongoing revolution, but as you point out in the next sentence the "revolution" is now almost 50 years old, and monitoring environmental change with high res satellites is now a pretty orthodox thing to do. However, we are in the middle of a micro satellite resolution, with one provider (Planet) aiming to cover the entire globe everyday, currently at a much higher

frequency than Landsat/sentinel with a much higher spatial resolution and NDVI capability. This is not mentioned in this paper, and it is obviously commercial in nature, but it should be noted that this is a rival platform with similar ambitions and capability, that is set to grow in the future.

Response:
We will remove the word "has" from line 25.

We are also very excited about the current micro-sat revolution. However, we respectfully disagree that a private corporation like Planet Labs is a "rival platform" or that the corporation has "similar ambitions" to a government-funded open access operation such as Landsat or Sentinel.

One current solution could include building an advanced HazMapper platform suited for use within the Google Earth Engine Python or JavaScript API, which allows users to bring in external datasets for analysis (such as those they purchased from Planet or another commercial provider). This is significantly outside the scope of the current HazMapper application but could be considered in the future.

Line 28: "subsequent satellite networks (e.g. MODIS, Sentinel ..." - MODIS isn't a satellite, maybe change to "subsequent sensors aboard different satellite constellations" or suchlike

Response:
We will modify the manuscript to read "networks *and payloads*" to capture the MODIS payload.

line 38: "scientific curious public" ! "scientifically curious"?

Response:
We will accept this suggestion and modify the manuscript.

Line 41: "HazMapper is useful for monitoring landscape change that results in disruption of surface vegetation" this seems an important point, as it is the entire basis of how HazMapper currently works, and should probably be in the abstract, and maybe the title. The authors point out their intent to add other approaches, both by their own efforts and through growing an online base of contributing developers, but that is for the future and not a research result being presented here

Response:
We will clarify this point in the abstract.

Line 42: "While the underlying mathematics are not entirely novel ..." my understanding is that the mathematics presented here is not novel, and the novelty comes from the combination of technologies and how they are made available? I would delete this line, unless I've missed some novel mathematics somewhere, in which case it should be made explicit what exactly that is.

Response:
We will remove the word "entirely" from the manuscript. We want to ensure the reader understands our contribution is not the mathematics or multispectral satellite index implementation, but the combination of technologies as the reviewer points out.

Line 43: "HazMapper democratizes ..." I'm wondering if democratizing is the appropriate word here – doesn't that imply some kind of collective decision making? I imagine HazMapper could be used in such a way by a group of people, but it doesn't seem to provide anything explicit to facilitate "democratic" decision making. It seems to me to be more about accessibility than anything else.

Response:
"Data democratization" is a common term in the data science and technology sectors. This is the idea of making data available and accessible to everyone. As such, we respectfully disagree with this comment and prefer the current language.

Line 50: "Because HazMapper is intended to be an emergency management tool, it is designed around user input variables" aren't all user interfaces formulated around user-input variables? I would skip this sentence

Response:
The interactive nature of HazMapper is unique in remote sensing data science specifically because variables are not hard-coded and analysis is not performed for fixed spatial extents, but instead, these are user-input variables. We prefer to leave this language as is.

Line 51: "Variables include ..." ! something like: "The user is able to control the following variables ... and cloud cover" - make an exhaustive list.

Response:
We will accept this suggestion and modify the manuscript.

Line 53: "Basemap options include : : : " ! "The basemap options are"

Response:
We will accept this suggestion and modify the manuscript.

Line 54: Missing "The" at start of sentence.

Response:
We will accept this suggestion and modify the manuscript.

Line 58: Sentence starting "Optical aerial..." duplicates point in next sentence and can be removed.

Response:
We will accept this suggestion and modify the manuscript.

Line 65: I assume the greenest pixel technique is something that comes built in to Google Earth engine? If so, is there a reference for it?

Response:
Yes, it is built into GEE. There is no peer-reviewed reference for this particular function, but additional documentation is available here:
https://developers.google.com/earth-engine/apidocs/ee-imagecollection-qualitymosaic

Line 74: Might be an idea to explicitly state what "pixel fractionation" is

Response:
We will clarify this topic in the manuscript.

Line 87: "Available basemaps on the platform include" repeating information from line 53? If so, delete.

Response:
We will accept this suggestion and modify the manuscript.

Line 89: Is "Heads-up" digitization different from regular digitization?

Response:
Yes, it is different from manual digitizing (http://wiki.gis.com/wiki/index.php/Digitizing), however, we concur that in the modern computational environment, heads up digitizing is becoming the norm. To this end, we will accept this suggestion and modify the manuscript.

Line 96: "For this article and shared finds ..." Not obvious what "shared finds" are – please rephrase.

Lines 106 -126: Section 3 is titled "Earth Engine vs. Traditional GIS Environments".However
in this section it's not entirely clear if the virtues being extolled are those of HazMapper or
Earth Engine. E.g. , lines 122-126 – both of these sentences apply to Google Earth Engine
alone if one is proficient with Javascript and the GEE API? Would be good to rewrite this
and make more explicit what the advantages of GEE are, and what HazMapper builds on
top of that.

Lines 107-112: This is quite a long winded way of saying that the main aim of HazMapper is
to make satellite image analysis available to less wealthy areas. Consider condensing into a
sentence or two, rather than a paragraph. Plus it occurs to me that Google Earth Engine
has already solved the problem of making modern scientific analysis available - it seems to
me anyone with the computational resources to use HazMapper can use Google Earth
Engine as well. Isn't HazMapper really about expertise, you're trying to make it available to
those who aren't going to learn JavaScript and the GEE API for whatever reason?

Line 117: "timestamp" ! "take a snapshot of"? The method uses greenest pixel composites,
which seem fundamentally diachronous in nature, whereas "timestamp" to me implies an
instant in time

Line 121: "HazMapper's source code" - > "The source code for HazMapper..." or "The
HazMapper source code...". Plus the source code should really be available in an online
repository and linked to from the paper.

We will accept this suggestion and modify the manuscript. The URL for the source code is listed in line 333 and will be posted in an online repository.

Also, what license will it be made available available under?

Response:
License information will be provided in the revised version of the manuscript.

Line 129: "difficult to overstate ..." I would rephrase to be less effusive. Also, reference seems to be for radar, which has different concerns to optical sensors, which are the subject matter here?"

Response:
We will remove this paragraph from the manuscript.

Line 138: "HazMapper is intended to facilitate future research..." This seems to be repeating the sentiment from the end of the introduction – I would expand that section rather than repeating here. Unless maybe you mean to say this future research will be added to the case studies, in which case I would say that explicitly here.

Response:
We will remove this paragraph from the manuscript.

Line 143: "$", "USD" or whatever the appropriate currency code is (assuming US Dollar is the currency).

Response:
We will accept this suggestion and modify the manuscript.

Line 146: "Significant research" significant in what sense? Needs explanation

Response:
We will remove "significant" from the manuscript.

Line 152: "...analysis by trained professionals with access to high-powered computers and large storage capacity..." this point has been made before, I would remove this sentence

Response:
We will accept this suggestion and modify the manuscript.

Line 152: "Whether to provide ... " This reads a bit more like advertising copy than scientific journal text, would consider rephrasing. Plus I think this has been said before in the paper, just in a general natural hazards context, rather than in a specific context (mass wasting). Maybe best to remove.

Response:
We will accept this suggestion and modify the manuscript.

Line 178: "Acquisition schedules ..." This seems like a general statement about potential use of HazMapper, rather than something that was a part of this particular case study and should be in the discussion or conclusions section as part of a "potential use" section. It seems to me that the case studies function as a kind of results section in this paper, and should be limited to those results, rather than speculation on un-proven, future usage.

Response:
Excellent suggestion! We will recast our case studies section as the Results section, and include a new section 4 - Discussion.

Line 185: "Fatalities ... from the earthquake itself (Budimir et al., 2014" ! "Fatalities from co seismic mass wasting can be up to an order of magnitude greater than fatalities resulting from the earthquake itself (Budimir et al., 2014"

Response:
We will accept this suggestion and modify the manuscript.

Line 188: ": : : are not well understood for this event that occurred ..." !"are not well understood on account of this event occurring in a rural and remote : : :.

Response:
We will accept this suggestion and modify the manuscript.

Line 201: "HazMapper provides : : :.evaluation of empirical relationships between parameters such as moment magnitude ..." Seems to me this is about future work and so is out of the scope of the case studies presented here which function as a kind of results section of the paper. Again move to a "potential future work" section in the discussions or conclusions.

Response:
We will move this section to a paragraph in the Discussion or Conclusions section.
Paragraph starting 205: again mixing up future work and case studies. This part feels a bit like a research proposal.

Response:
We will move this section to a paragraph in the Discussion or Conclusions section.

Line 224: Again, referencing future potential – these aren't really results of the case studies and should be moved to the discussion.

Response:
We will move this section to a paragraph in the Discussion or Conclusions section.

Line 243: Future potential again

Response:
We will move this section to a section in the Discussion or Conclusions section.

Line 290: "advancement" ! "advance", "met with obscurity" ! "hindered

Response:
We will accept this suggestion and modify the manuscript.

Line 306: "democratize" see previous comments

Response:
"Data democratization" is a common term in the data science and technology sectors. This is the idea of making data available and accessible to everyone. As such, we respectfully disagree with this comment and prefer the current language.

Line 312: "...suggesting the extents..." this seems to be the core of what the approach presented here does, and it needs to be highlighted more

Response:
It is not clear to us what the reviewer means by this comment. We added a sentence to clarify that HazMapper is not a semi-automated method.

Line 314. " rapid response ..." it seems to me the appropriate timescale for something to be considered a "rapid response" for a natural hazard, at least as far as nonacademics are going to be concerned, is the timescale on which people's lives are lost as a result of the event and its aftermath, and two weeks is actually quite a long time in this context?

Response:

In mass wasting events, lives and property are lost within minutes, and even in resource-rich nations, cleanup efforts take days to weeks. In this context, we hold that identifying likely debris flows from a single large event in a developing nation within 2 weeks does qualify as rapid response.

Line 316: verification of maps produced by HazMapper could form part of a discussion section?

Response:
Verification is premature for a multispectral satellite index map. Future iterations of HazMapper that include semi-automation will require a full accuracy assessment.

Line 355: "See letter to the editors" - is this appropriate to have under "code and data availability", and will the letter be available to readers when the manuscript is finally published? Should any important information in the letter be moved into this section?

Response:
This comment was for the peer-review process to ensure the reviewers had a chance to gain access to HazMapper. It was never intended for publication and will be removed from the revised manuscript.

Equations 1 and 2 – do equations in this journal have captions like figures? If not, I would replace the captions with text in the main article, something like "where x is the variable for blah, y is the rate of blablah, and z is the magnitude of blahblahblah".

Response:
Excellent suggestion - we will revise the manuscript to this effect.

Figure 1. "Heads up digitize" - again, is this different from regular digitization?

Response:
Yes, it is different from manual digitizing (http://wiki.gis.com/wiki/index.php/Digitizing), however, we concur that in the modern computational environment, heads up digitizing is becoming the norm. To this end, we will accept this suggestion and modify the manuscript.

Figure 3. "All maps have same orientation" - unnecessary, delete – add N arrows to figs b,c,d if worried about ambiguity.

Response:
We prefer to not obscure the figures with unnecessary north arrows but still indicate to the reader that all figures have the same orientation. We would like to leave this as-is.

I was unable to reproduce the maps in this figure in HazMapper– it seems as if perhaps the rdNDVI is being thresholded somehow and overlain on the greenest pixel images in ArcMap? If this is the case, it is a bit misleading to be presenting this as an example of the successful use of HazMapper. Presumably it would be possible to add such a facility to HazMapper with relatively little effort, otherwise the figures should really be replaced with screenshots from HazMapper, (or at the very least it needs to be made more explicit that this is a more "advanced" analysis performed for validation purposes only, and that the facility will not be available to non-expert users within the HazMapper interface itself).

Response:
We have tested some user-driven color ramps in HazMapper and will implement in the future, but for the first iteration, believe a generic -50 to +50% change in rdNDVI red to blue color ramp best suits most users. This color ramp saturates at -50 and +50%. Values greater than this will have the same color at a 50% decrease or gain in rdNDVI. The download functionality of HazMapper is intended for users to download data for use in other geographic information systems software platforms (e.g., ArcGIS, QGIS, GRASS GIS, etc.,). We have posted our ArcGIS Pro compatible symbology files used to render the data presented in the figures on our website: https://hazmapper.org/resources-faq/

Additionally, a new figure 8 to address a comment from RC1 will include the default layout from HazMapper and a draft of this figure is included below.
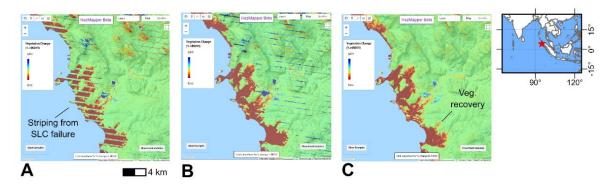

Figure 8. $rdNDVI$ change detection images and greenest pixel composites following 26 December 2004 tsunami in Indonesia resulting from the Sumatra–Andaman earthquake. Parameters - Dataset: Landsat-7, Event Date: 26 December 2004, maximum cloud cover: 100%, and slope threshold: 0.01°. Pre-Windows: 1, 2, and 12 months, Post-Window: 1, 2, and 12 months for panels A, B, and C, respectively. $rdNDVI$ across the event illustrates tsunami inundation zone and resulting loss in vegetation. Striping in the data from the scan-line corrector failure in Landsat-7 is evident in a short look window (e.g. 1 month, A), but these artifacts are reduced by increasing the pre- and post-event windows (B and C). By 12-month pre-post periods (C), the striping is significantly reduced in results, however, vegetative recovery is also present in this longer post-event cycle that captures the first growing season following the tsunami. Screenshots of HazMapper application, example accessible at https://go.ncsu.edu/hazmapper-indonesia-tsunami.