

The 2022 Rainfall-Triggered Landslide-Tsunami Disaster in Pilar, Abuyog, Leyte, Philippines and its implications for coastal hazard assessment

Reviewer 2 (Sebastian Watt)	Authors' Comments
Abstract: It would be helpful to provide specific information in the abstract on distances and timescales (rather than just describing these as short pathways) to highlight the challenges associated with events of this type (e.g. potential for preparedness and warning).	This part of the abstract will be revised to: “Analysis of landslide–tsunami coupling indicates that wave generation was governed primarily by high-momentum impact conditions, with debris flow velocities of up to 25 m/s and source-to-shore map distances between 550-1020m, limiting energy dissipation prior to coastal entry.”
Line 70: The description of previous potential landslide-generated tsunamis is unclear in this sentence. It would be helpful to expand on this slightly to clearly explain the previous potential landslide generated events in the Philippines, their location and scale, and notes on the source (particularly if this is uncertain). Perhaps this would be best presented as a short table, to place the event described here into a national context.	This sentence will be revised to: “Dohmen et al. (2025) marked a few ‘Landslide-Triggered Tsunamis’ in the Philippines in their global inventory of such events, however, as we revisit their source for the database (Paris et al.,2014) these events were described as historical and probable volcanic tsunamis in Taal Caldera, Babuyan Archipelago, or was “confused with storm surges” according to Paris et al. (2014), instead of landslide-triggered tsunamis.”
Did the interviews follow a specific set of questions? If there was a formal set of questions, this would be useful to share as a supplementary document, as it could act as a useful guide for similar studies of this type and also help interpret the way in which information was obtained.	The interviews were semi-structured. We’ll include the guide questions used by the team as a supplementary document.
Line 128: “distinguishing” rather than “establishing”?	This sentence will be revised to: “A key step was distinguishing the spatial extent of tsunami impact from that of the landslide deposits based on observed damage patterns.”

Line 130: It's unclear how h was derived to establish run-up heights of the debris flow (the implication is that these are debris flow heights, not tsunami run-up, unless I've misunderstood). I understand that this marks the maximum inundation, but how was the baseline established, and what was the reference point? (from the channel, or from the deposit surface?).	Yes, these are debris flow run-up heights, measured from the pre-debris flow surface. We'll revise the sentence to: "From features like these we estimated velocities using debris flow runup heights (Eq.1): $v = \sqrt{2gh} \quad (1)$ where v is the flow velocity, g is the acceleration due to gravity, and h is the runup height measured from the pre-debris flow surface."
L141: I can understand that total destruction could be a marker of tsunami damage, but such damage patterns could also be produced by debris. Presumably, though, the overall spatial pattern of damage also guided the interpretation (i.e. spatial relationship to the debris flow margins, or the landward damage pattern observed in the area impacted by the tsunami)?	We will revise this to: "Beyond the margins of the debris-flow deposit, houses were reduced to rubble, with only the floors remaining intact. The absence of soil smudging suggests that these structures were destroyed by wave impact from the subsequent tsunami. Rafted-debris lines and the denuded cliffside were used to estimate the high-water mark and the landward extent of tsunami inundation (Fritz et al., 2007)."
Geological context of the landslides: At several places, the volcanic geology is alluded to as significant, but it is hard to find a clear, comprehensive description of the source area. The detail is a bit disparate, mentioned at several places, but not providing a clear picture of this important element of the event.	Line 216-219 states "The source area is underlain by poorly sorted gray to reddish-brown volcanoclastic deposits composed of angular to subangular clasts embedded in a sandy-silty matrix. Clasts range from gravel to boulder-sized. The landslide deposits are weakly consolidated and highly weathered."

At Line 75, the reference to “volcanic terrain” implies that the volcanic nature of the setting is the important element, but this statement is not really explored. It would be informative to pick up this point in the discussion to consider if volcanic slopes, or more specifically, particular volcanic or volcanoclastic rock types, are particularly prone to mass wasting of the Pilar-event type, and what the exposure of such settings is in coastal environments of the Philippines.	Many coastal areas in the Philippines have steep slopes behind them; a Pilar-type event may occur even if it’s not volcanic or volcanoclastic in nature. We instead seek to emphasize that awareness of this hazard interaction or cascade is needed in these areas. The sentence will be revised to: “As the first well-documented event of its kind in the Philippines, it highlights the urgent need to improve hazard assessments in inhabited areas near steep coastal terrains.”
The geology is described again around Line 90, but the structural elements are not properly explained (are the rocks in the landslide source area steeply dipping, faulted etc?). Faults are referred to in the area, but is there any information on the specific nature of the source region in terms of fracture density or deformation?	Previous works referred to in Line 90 (Sajona et al., 1997; Mines and Geosciences Bureau, 2010) only described the local geology and the regional tectonic structure, no fault was previously mapped in the Pilar area (active fault maps mark the Central Leyte segment of the Philippine Fault Zone to be 9kilometers away). The faults in Pilar needed further study, but due to safety issues (the source area structures were obscured by the slumping unit), we were not able to do that yet.
L217: The statement of the source geology here notes that the area is “underlain” by volcanoclastics. Please clarify if this was the rock that actually failed, or if this is the unit underneath the rock that failed (the wording is ambiguous). Did the failure occur on a boundary between two lithologies, or within this volcanoclastic lithology? From the description, it sounds like the failed material was a very poorly sorted volcanoclastic unit (clasts up to boulder sized). Can the authors provide any	At least 3 curved slip surfaces cut through the layers described in L217 (as well as in L269-271), at various levels (the western scarp being the highest in elevation). These layers were described from the drone footage of the scarp and the slumping units, but below this, the rock sequence is obscured by the muddy veneer on the slip surface caused by the latest landslides/slumps. It wasn’t possible during the fieldwork to see if the failure surfaces of DF1 and DF2 were parallel to any lithological boundary.

further information on the nature of this unit and its extent, which may help understand why it was prone to failure? A few further details are provided at L270 (and at L260, where this is described as a weathered volcano). Further information is given again later on, where the coarse clastic unit appears more confined, so the overall description of the source lithology becomes quite confusing to the reader. Because the properties of DF1 and DF2 are notably different (Fig 8 and as described in the text), this seems particularly important to understand what failed initially, the nature of those materials, and how they may have been affected by the intense rainfall events. It would be better to consolidate all these descriptions of the source geology into one place, to provide a detailed description of the failure regions's stratigraphy and properties.	We could not take samples from the source area. Lithological identification was only possible from the OL, DF1-DF2 deposits in roadcut, the debris fan and levee deposits. As this was also commented on by the first reviewer, we will reorganize the geologic data presentation, and merge these sections. However, we'll retain the separate section on the general geology of Leyte island described by previous works in the introduction.
Other potential triggering factors: Two intriguing elements of the failure emerge in the discussion (knowledge about tension cracks along the strike of the failure plane; and the occurrence of an earthquake the previous day), but are not developed at all. Furthermore, the timing of the event is surprising (perhaps?) in being around two days after the peak rainfall intensity. Alongside an evaluation of the properties of the initial failure, it would be informative if the authors could develop this slightly in the discussion.	We will include details of the M2.5 earthquake, on April 11, 2022 but we are limited to the available data provided by PHIVOLCS (https://earthquake.phivolcs.dost.gov.ph/2022_Earthquake_Information/April/2022_0410_1728_B2.html).

The statement at L221 about previous tension cracks along the line of the failure is very interesting but only very briefly mentioned. How were these cracks noticed in 2021? Were these reported by local residents or linked to concerns around ground deformation or seismicity, or did they just happen to be observed during a routing survey? Did the survey cover the area that was ultimately the source of the landslide?	The tension cracks were reported by the local residents in 2018 and they requested a site inspection from the Mines and Geosciences Bureau. We could not reach the area on foot in 2022 due to the weather conditions and the risk of further collapse. We tried using the drone, but the area behind the scarps was beyond the signal capacity of our equipment.
L457: The occurrence of a shallow earthquake is briefly mentioned, a day before. This would coincide with the peak of the rainfall and seems a potentially important additional triggering factor. Can details be provided of the magnitude and location of the earthquake, and likely shaking intensity in the source region?	Yes. We will include details of the M2.5 earthquake, on April 11, 2022 but we are limited to the available data provided by PHIVOLCS (https://earthquake.phivolcs.dost.gov.ph/2022_Earthquake_Information/April/2022_0410_1728_B2.html).
Eyewitness observations: Table 1 and L232: The first line in the table and the statement described at L232 is surprising, in implying that small-scale feature (cracks in the slope and gradual movement) could be observed from offshore. Does this imply that the deformation was therefore large scale and visible from some distance (presumably from around 1 km away from the source, if I'm reading the scale in fig 3 correctly), or does it raise questions about the nature of what was observed, or is there perhaps some uncertainty about timing, and could this observation be coincident with the start of the landslide?	The eyewitness (Offshore Fisherman) narrated the timing of slow movement at around 2pm while they were fishing offshore, through the 'burst' (the start of debris flow) while he was already onshore in Malaguicay between 3pm-4pm (also corroborated by many witnesses), the rescue efforts, then another increase of sea level after (we associated this with the 2nd main failure). The crown area is indeed visible offshore, at certain locations where boats pass. We can add a photo that supports this (see sample photo on the next page).

	 This is the video when we were traversing the route similar to what fishermen would take: 🔥 MVI_4733.MOV
Field observations: L261: This sentence is a bit unclear in terms of the geological relationships in the source area (“landslide units” – are these the fresh deposits?).	For clarity, we’ll revise this to: “Although two distinct 100-meter-wide, 30-meter-deep scarps are immediately recognizable from satellite images and in the field, both have brown muddy veneer obscuring their cross-cutting relationship; hence, the sequence of slope failure is not yet certain.”
The distribution of tsunami run-up information in Fig. 9 is very interesting. How specifically were the heights in Malaguicay and Bahay obtained. Is this from eyewitness data, or field measurements? If it’s the latter, how was this evident so long after the event? Describing these details would be helpful for future post-event surveys. Additionally, were the eyewitness height observations in Pilar consistent with field measurements, or was one or other systematically higher (again, useful information to help	We will include this statement at Line 400 Section 5.2: “At the near-field site of Pilar, tsunami run-up information was derived primarily from rafted debris, which was consistent with eyewitness accounts. In Barangays Bahay and Malaguicay, where remaining rafted debris were minimal or nonexistent, we relied primarily on eyewitness accounts, supported by video recordings.”

interpret different sources of obtaining height information). For the distal sites, was there any evidence of a deposit left by the tsunami? There are very few such deposits described in the literature, so understanding if any indicators were preserved, and what these were like, would be valuable to future studies and assessments.	
Discussion: The discussion provides an insightful wider context and comments on many elements of the event that have wider implications for this hazard type and the risk from relatively small-volume coastal landslides. A few comments: L460: Very interesting wider context, with 11 landslides reaching the coast as part of this event. Can any evaluation be made of the pathway distances of these other landslides and their total volume, to evaluate why the Pilar event provided an effective tsunami source whereas the other events did not? Is the source-rock type of these other events known? And was the Pilar event larger, or simply nearer the coastline? Is there any information about the timing of these other events, and did they also lag the peak rainfall intensity?	We were not able to conduct fieldwork and drone survey to more accurately estimate volume of the other landslides since the roads to them were destroyed. However, we can include a comparison of extent (sq. m) as a supplementary file. We don't have estimates of time as many of these are in uninhabited sites, they were only identified from satellite images, with some verified by reports of other agencies.
L534: The maximum run-up for the Anak Krakatau 2018 tsunami, evident from trim lines on both Rakata and Sertung, nearby islands, was 80-90 m (see, for example, Grilli et al., 2021, Fig. 11: Modeling of the Dec. 22nd 2018	Table 3 is updated to correct the data on Anak Krakatau: up to 85 m tsunami runups in Rakata Is. and Sertung Is. (near-field) and

Anak Krakatau volcano lateral collapse and tsunami based on recent field surveys: Comparison with observed tsunami impact - Marine Geology). The point is still reasonable, that relatively small landslides can still cause highly damaging tsunamis, but the Anak Krakatau failure was several orders of magnitude larger and, despite the open water setting and greater distances to the nearby impacted shores, the run-up was substantially higher. This should also be corrected in Table 3.	up to 13.5 m tsunami runups in Java and Sumatra (far-field) Reference: Grilli, S.T., Zhang, C., Kirby, J.T., Grilli, A.R., Tappin, D.R., Watt, S.F.L., Hunt, J.E., Novellino, A., Engwell, S., Nurshal, M.E.M., Abdurrachman, M., Cassidy, M., Madden-Nadeau, A.L., Day, S., 2021. Modeling of the Dec. 22nd 2018 Anak Krakatau volcano lateral collapse and tsunami based on recent field surveys: Comparison with observed tsunami impact. Marine Geology 440, 106566, https://doi.org/10.1016/j.margeo.2021.106566.
A further volcanic landslide tsunami in a lake context that could be included for comparison, also likely triggered by prolonged intense rainfall, is that at Yate volcano in 1965 (with an approximately 60 m run-up), see: Watt et al., 2009, Landslide and tsunami hazard at Yate volcano, Chile as an example of edifice destruction on strike-slip fault zones Bulletin of Volcanology Springer Nature Link	We'll include the said example for comparison in Table 3 and in the corresponding discussion.
Figures and supplementary data: Figure 1: The location map could be clearer. The left panel is very dark, and the detail in the other two panels is difficult to see, especially the text, labels and particularly the legends.	Thank you for this feedback, we'll work on the color balancing and label size and contrasts.
Figure 3: This would benefit from being larger, particularly key details around the source area and tsunami impact zone. It's hard to see features at the current size.	We can enlarge Figure 3A to maximize the width of the page (with margins) for the drone orthophoto, and provide an inset pre-landslide DEM that highlights the geomorphological features of the study area.
A pathway profile would also be very helpful, because there isn't a clear elevation map of the source area	We will add the profile in Figure 3.

provided (the only mention in the text is of a source elevation of 200 m, but to understand the terrain, a profile along the channel is really needed).	
The supplementary files provide a useful further set of figures, mainly interpreted images and photographs. These would likely be better compiled into a single document, as they all represent additional interpretation of field observations.	We'll compile the supplementary figures in a single document.
For long-term recording of observational data, the field sites and details of run-up measurements (for both the debris flow and tsunami) should be provided as a supplement to the paper (with coordinates, types of measurement, height and inundation etc.). There are very few datasets of this type, especially for landslide tsunami, and such data would enhance the value of this for future studies (these data should be associated with the paper to ensure accessibility, even if the broader datasets (drone footage etc.) are in a separate repository).	Thank you for pointing this out. We agree that field measurements are valuable and relatively rare, and should therefore be documented and reported for future reference. The links to the shapefiles of the sample and measurement sites in Figure 9 were in the provided data repository. But to make it more readily accessible, we also added a supplementary table containing the tsunami run-up heights and corresponding coordinates.