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# Post-liquefaction reconsolidation of coastal area in Talise Beach, Palu, Indonesia

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**Abstract.** Periodic generated, sequence of earthquakes with magnitude 7.5 at a depth of 10 km occurred in Palu Koro fault, Central Sulawesi, and was trigger tsunamis wave in Talise beach reach coastline in few minutes. It causes entire coastline become extremely attacked and moves gravitationally of the ground at a slope as well, known as flow of liquefaction. Reconsolidation of coastline structure in post-liquefaction event in Palu's Talise beach had been heaving due to devastating aftermath of the earthquake and tsunami that hit Sulawesi. Lack and rough terrain are intensively associated with the difficult to assess post-area, so remote sensing can be efficiently and quickly to identify potential post-area occurrence. Satellite multispectral such as Sentinel, and SRTM DEM applied with a new approach to corporate post-event liquefaction in Talise beach, Central Sulawesi, Indonesia. In this result, we depict the 3D surface topography of pre and post event to analyse the liquefaction impact. We found the differentiation approach of pre and post event imply the liquefaction in variation of dimensional ratio. Therefore, our hypothesis may be useful to the preliminary research for mitigation and revitalization in post-area.

## 1. Introduction

The phenomenon associated with loss of shear strength of existing soil structures due to an increased pore water pressure characteristic of sands and coarser than clay and colloids cause stress of soil so that the soil becomes saturated statically or dynamically, which is called liquefaction [1]. Because it is saturated, the land becomes unstable which can trigger the mass movement of soil to sliding or liquefying an inclined surface. Liquefaction commonly occurs after an earthquake, the earthquake reported on 28 September 2018, close to Palu Koro Faults, Central Sulawesi, triggers tsunami reaching height of over three meters [2, 3]. The stretch of Palu Koro fault activities pushed the side of the fault together generates 30 earthquakes daily over the last four months before. Its peak rocked landslide under 10 km on 10 seconds [4]. The potential level of coastal topography, where soil usually settles temporarily, can also result in surface movement of materials by water when a saturated condition in the soil so its acts as a fluid.

As evidence of seismic activity, Talise beach is listed as one of the earthquake-stricken areas and soil liquefaction. Talise beach stretches from Palu to Donggala in East Palu District, Central Sulawesi province. The explanation of earthquake shaking impact and potential level of coastal topography may lead the reason of liquefaction possibility. The general topography of Central Sulawesi is extensive uplifting, faulting, and coastal subsidence (sinking) of the Earth's surface, especially on Talise beach which is categorized potentially subsidence-uplift of coastal lowland where it is discontinuous and relatively narrow [5]. Coastal lowland contributes to high liquefaction susceptibility is in this region by the characteristic of sands and coarser to loss of shear strength [6, 7].



Communities along the surrounding coasts of Talise beach were seriously affected by tsunami an estimated 1.5 million people [8]. The significant impact of liquefaction leads thousands of structures collapsed or rendered uninhabitable, economic disruption and even loss of human life. In Indonesia, many incidents were assigned where a devastating earthquake involving the potential soil liquefaction was suspected between 2004 – 2018 in Indonesia, such as the earthquake that occurred in 2004 Aceh [9], 2005 Nias – Simelue [10], 2006 Yogyakarta, 2010 Mentawai [11], 2019 Bali, 2019 Northern Sulawesi, etc. Most of the phenomenon occurs in lowland area, such as coastal area.

Previous studies have shown the liquefaction with the great East Japan Earthquake was struck on March 11, 2011 in 190 municipalities and 13 prefectures along the shores of large rivers along the Tokyo Bay coast from Tohoku to Kanto areas [12]. Obermeier et al. from USGS observed earthquake-induced liquefaction features in the coastal setting of South Carolina and in the fluvial setting of the New Madrid seismic zone by interpreting the geologic criteria of the various features [13]. Liquefaction features due to paleoearthquakes (>5 Mw) in the coastal setting of Christchurch (South Island of New Zealand) is prone to liquefaction because faster fluidization in the surface soil profile [14]. Takegawa et al. describes the correlation earthquake and tsunami in Pacific coast of Tohoku on 11 March 2011 to coastal area are a significant impact on the scour profile [15]. Wang et al. investigate coastal feedback of dynamic liquefaction because the compaction of saturated granular soil [16].

Multidisciplinary approaches have effectively assessment to monitor soil liquefaction while minimizing cost, environmental impact and other related to liquefaction mitigation. Rapid development of materials and science technology has made available new materials suitable for improving the liquefaction resistance and enabling other liquefaction mitigation techniques [17]. To raise some crucial phenomenon and encourage further research and discussions, investigations on the recently developed liquefaction mitigation methods by using satellite imagery Sentinel, Landsat and field survey on sophisticated technology remote sensing in terms of effectiveness surface mapping are reviewed in this study.

## 2. Materials

An encouraging response to active or passive satellite has been released to derive surface data which tracking zones and implementation of mitigation strategies. The core dataset is satellite achieve of Landsat 8, Sentinel 2, SRTM DEM, and field survey with a GPS unit. This study selects Palu city and its surroundings as demonstrating area where there were many deadly high-low land possibilities. We use methods to the field-based mapping of liquefaction by satellite and in situ measurements.

### 2.1. Data Achieve

We divided materials become two categories, digital material and field-data survey. Digital material Landsat 8 OLI is launched on February 11, 2013 as a collaboration between the United States Geologic Survey (USGS) and National Aeronautics and Space Administration (NASA). Landsat 8 OLI has specification 30 m of spatial resolution and 16-day revisit period which is downloaded from <https://landsatlook.usgs.gov>. Sentinel 2 is an imagery product from ESA Copernicus with higher spatial resolution than Landsat 8, 10, 20 and 60 m, shorter revisit period 5 days which is downloaded from <https://scihub.copernicus.eu>. SRTM DEM or Shuttle Radar Topography Mission Digital Elevation Model is downloaded from <https://earthexplorer.usgs.gov/> with spatial resolution around 30, 60, 90 m.

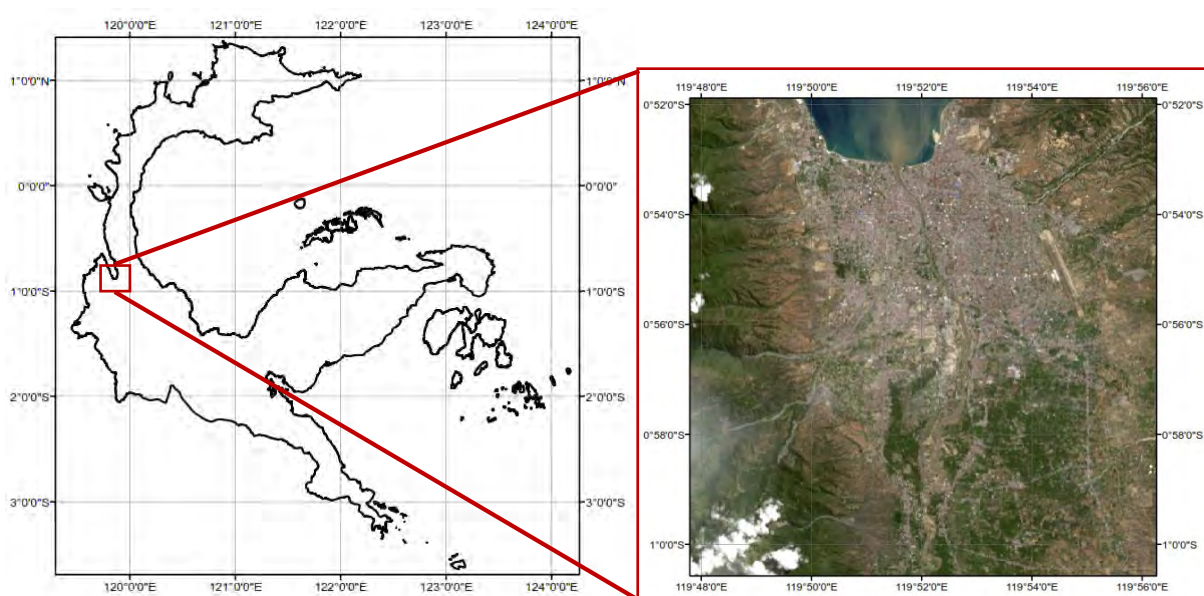
**Table 1.** The characteristics of material with further specification (resolution, overpass date, path/row or tile

	Resolution	Overpass date	Types/Path/Row or Tile
Landsat 8	Spatial Resolution	8 March 2018	L1TP_114061
	: 30 x 30 m	14 July 2018	L1TP_114061

	Temporal Resolution	16 September 2018	L1TP_114061
	: 16 days	2 October 2018	L1TP_115060
		25 October 2018	L1TP_114061
		18 March 2019	L1TP_115061
Sentinel 2	Spatial Resolution	22 October 2018	L1C_T50MRE
	: 10 x 10 m	10 January 2019	L1C_T50MRE
	Temporal Resolution		
	: 5 days		
SRTM DEM	Spatial Resolution	10 August 2018	N01E098.SRTMGL1
	: 30 x 30 m		

## 2.2. Area of Interest

Study area has geographical center with latitude  $-0.8679^{\circ}$  S and longitude  $119.9047^{\circ}$  E in Palu city and its surroundings. The specific boundary area (for Talise beach) stretches around  $0^{\circ}52'0''$  S to  $1^{\circ}0'0''$  S and  $119^{\circ}48'0''$  E to  $119^{\circ}56'0''$  E.



**Figure 1.** Study area in Talise Beach and its surroundings

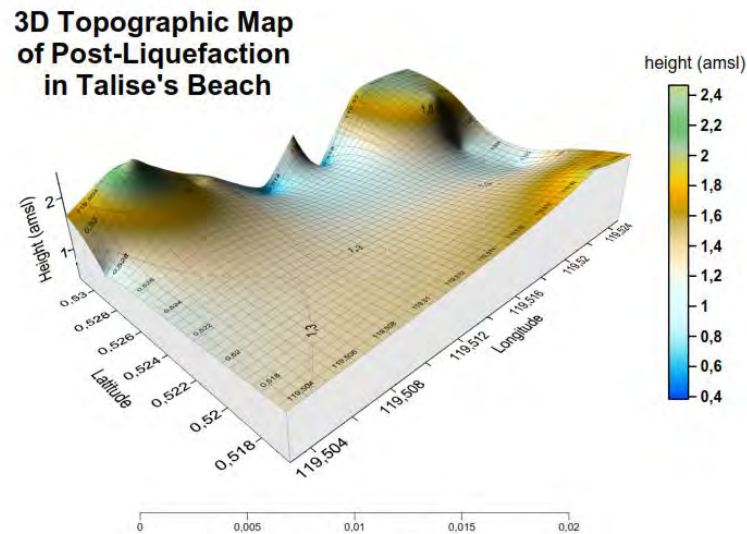
## 3. Method

In-situ data were collected where researcher went to the post-earthquake and tsunami zones in Palu, Central Sulawesi on November 2018 to provide the ground control point for reference in georeferencing data of digital imagery. Geographical coordinate, z-axis (height) and some pictures as evidence of the phenomenon is captured. This information provides the expected detail liquefaction map in 2D and 3D. Furthermore, 3D mapping is built based on its information by the surfer algorithm. Additionally, each parameter, supported by land change, height, post-event, is further divided into before and after phenomenon to define how the particular relation for each hypothesis. Finally, the profile of cloud land surface change will present in percentage can be determined.

## 4. Result and Discussion

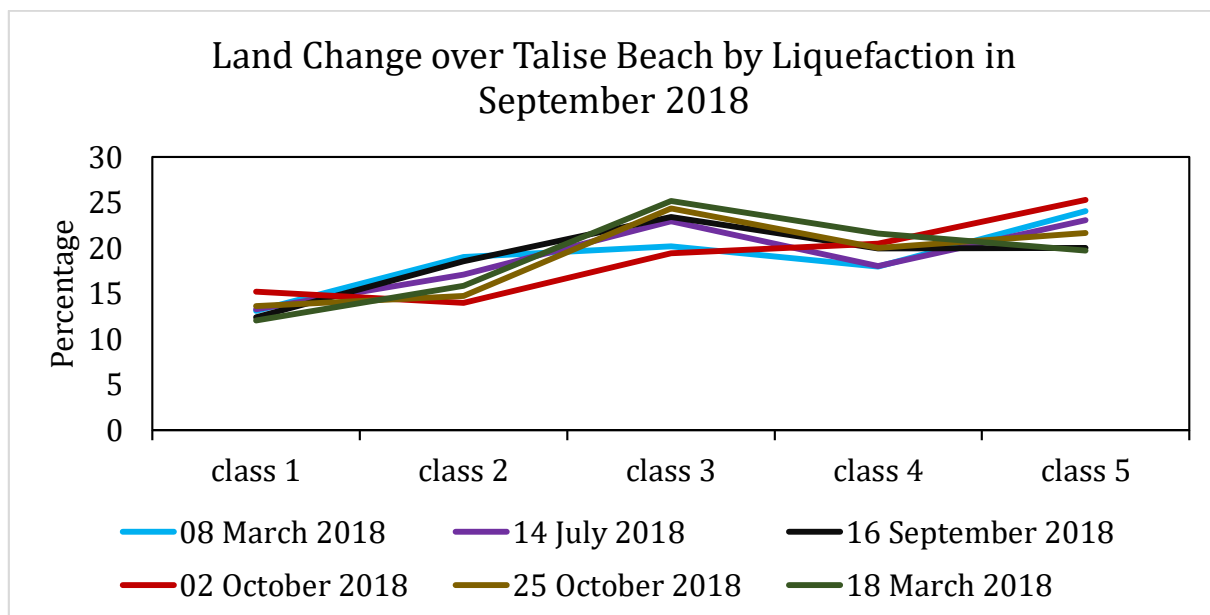
Land surface of Talise beach was represent in Figure 2 that distribution after liquefaction from November 10 – 16, 2018. This image shows the differences of altitude from 0.4 to 2.4 amsl that means

there is the 2 m differences along the post-event of liquefaction. Generally, 3D topographic mapping of post liquefaction in Talise beach represent the real relief off.



**Figure 2.** 3D topographic map of post-liquefaction in Talise Beach. Color scale depicts altitude from low to height.

Talise beach is the only liquefaction-impact area that is located closest to the shoreline. Figure 3 shows how the liquefaction changes the surface relief in before and after phenomenon. Most of area becomes soil-clay-sands as class 1 and class 2. And also, the vulnerability of the area is thought to be due to the presence of clay-sand particles made from metal transition compositions which can trigger liquefaction. This allegation is strengthened by the existence of laboratory results from samples taken in the Talise Coast liquefaction region by utilizing XRD technology to determine the arrangement of particles containing metal transition  $M / TiO_2$  ( $M = Fe, Co, \text{ and } Mn$ ). Metal transition particles have been previously studied as a trigger for the vulnerability of the region to experience liquefaction.



**Figure 3.** Land Change over Talise Beach by Liquefaction in September 2018

## 5. Conclusion

Talise beach has the potential level of coastal topography, where soil usually settles temporarily, can also result in surface movement of materials by water when a saturated condition in the soil so its acts as a fluid. It is also categorized potentially subsidence-uplift of coastal lowland, and deadly high-low land possibilities. We found that the Talise beach and its surrounding is covering by clay-sand particles made from metal transition compositions which can trigger liquefaction.

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