HEAVY RAINFALL INDUCED FLOOD AND LANDSLIDE IN BENGKULU, INDONESIA

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ABSTRACT: Indonesia is one of the countries with a significant number of flood and landslide events induced by heavy rainfall that sustain significant losses. Synthetic Aperture Radar (SAR) images by Sentinel-1 are employed to investigate the impacts of heavy rainfall induces landslide, which has a high temporal resolution and easily accessible. The RGB composite detected flood and landslide areas from Dual-polarimetry by Sentinel-1. In this study, flood and landslide areas in the Bengkulu area in Indonesia were detected by Sentinel-1 data on April 27, 2019. Simultaneously Rainfall data from the Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG) was analyzed the hourly rainfall and cumulative rainfall to determine the possibility of flooding and landslides in their area. As a result, One of the rainfall observation stations, namely the ARG BP3 Tes, observed cumulative rainfall data, which reaching 5588.8 mm/day, with the highest hourly rainfall is 541.2 mm/hour on April 26, 2019, Google Imagery on May 2, 2019 showed some landslide's locations in the mountainous area. The landslide generates sediment that directly transports to the Batang Simpangaur river and causes the river's bottom shallower than usual conditions, which magnified in Bengkulu flooding.

INTRODUCTION

Indonesia has high frequently affected by landslides and flooding areas induced. Based on a report from Badan Nasional Penanggulangan Bencana Nasional (National Agency for Disaster Countermeasure of Indonesia/BNPB) (2019b), in 2019, Indonesia has landslides (1481 events) and floods (1271 events) took the fourth and fifth positions after forest and land fires (3276 events), tornadoes (1700 events), and drought (1529 events). In the same year, some floods became a deadly natural disaster, with 474 people dead and missing and landslides in the second place with 145 deaths and missing cases. These areas experienced floods were Papua (193 died), South Sulawesi (98 died), and Bengkulu (74 died), while the landslides in West Java and South Kalimantan (20 died), Bali (19 died), North Sulawesi (16 died).

This study focused on the Bengkulu flood and landslide disaster, April 27, 2019, caused by heavy rainfall on April 26, 2019 (CNN Indonesia, 2019). This flood and landslide disaster has caused much damage; affected victims numbered 13,000 people, with victims displaced 12,000 people, 29 dead, and 13 lost (BNPB, 2019a). While material losses were reported as follows, 184 houses were damaged, education facilities damaged seven units, dead livestock animals 211 animals, bridges and damaged roads 40 units, and fisheries/marine facilities and infrastructure nine units. Most victims were due to landslides that occurred at the mountain (Firmansyah, 2019).

Rainfall data provided by BMKG, the hourly rainfall, and cumulative rainfall(daily) use to determine the possibility of flooding landslides occur. Sentinel-1 was observing the situation on May 5, 2019. Sentinel-1 is a satellite SAR developed by European Space Agency (ESA) and has been operating for disaster monitoring. Sentinel-1 is C-band; SAR has the advantages of penetrating the cloud and can use in any weather conditions (Tavus et al., 2018; Antara et al., 2019). Sentinel-1 use for investigation before and after the event occurs and for knowing the sediment change after the event.

DATA AND METHOD

The rainfall data were obtained from BMKG on 14 Automatic Rain Gauge (ARG) and 2 Automatic Weather Station (AWS). Rainfall data collected from April 26, 2019, at 00.00 Western Indonesian Time (WIB) until April 27, 2019, at 00.00 WIB. Geographic Information System (GIS) interpolated rainfall distributions using the Inverse Distance Weighted (IDW) method, which makes the assumption value close to another one (ESRI n.d.). In this case, Rainfall conditions and rainfall intensity in Table 1 is employed to interpolate cumulative rainfall value and the group.

Table 1. Rainfall conditions and rainfall intensity in Indonesia (Mori, 2003).

Rainfall Condition	Rainfall Intensity (mm)	
	1 hour	24 hours (day)
Very light	< 1	< 5
Light	1 – 5	5 – 20
Moderate	5 – 10	20 – 50
Heavy	10 – 20	50 – 100
Very Heavy	> 20	> 100

On the other hand, The Sentinel-1 data with mode IW GRDH and Dual-polarimetry (VV+VH) from ESA at Copernicus Services Access Hub (https://scihub.copernicus.eu/) scene observation before the event (April 23, 2019) and scene observation after the event (May 5, 2019). Red; Green; Blue (RGB) images were composited by the Sentinel Application Platform (SNAP) using the following equation (1).

$$R = 20 * \log10(|VV_{after}|)$$
$$G = 20 * \log10(|VH_{after}|) \quad \text{.....} \quad (1)$$
$$B = 20 * \log10(|VV_{before} + VH_{before}|)$$

Where $|\ |$ denotes absolute value and 20*log10 is the operation to convert to dB scale. The RGB composite can easily interpret the affected areas after the red color event before the blue color event (Jo et al., 2018).

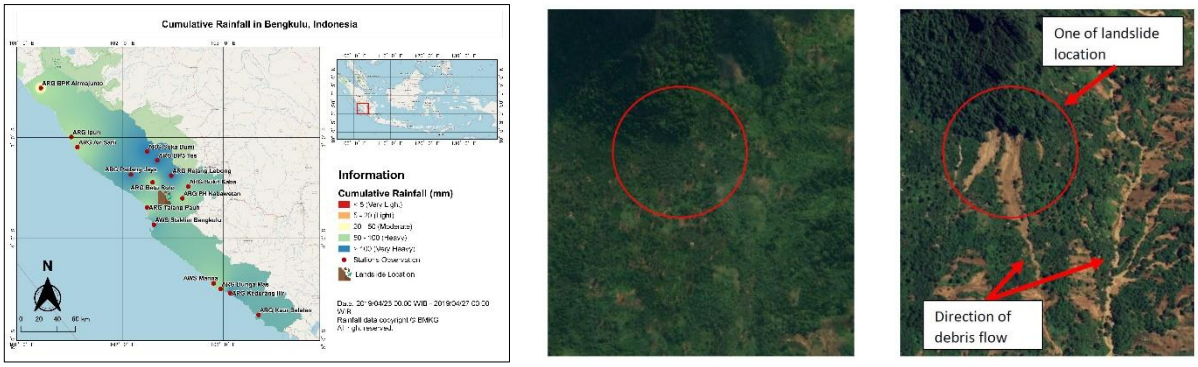
This research also used Google Imagery on Google Earth Pro to check the landslide location, debris flow direction, and the affected areas by visualization. The imagery is provided by CNES/Airbus (2019) and Maxar Technologies (2019).

RESULT AND DISCUSSION

Figure 1(a) showed the cumulative rainfall distribution map and the Bengkulu region's information experienced flooding with very external coverage, namely Kaur, South Bengkulu, Bengkulu City, Bengkulu Tengah, North Bengkulu, Kepahiang, Raja Lebong, and Lebong. Figure 3(a) and Figure 3(b) showed the flooded area which occurred due to high rainfall on July 26, 2019; one of the rainfall observation station, namely the ARG BP3 Tes, even providing cumulative rainfall data reaching 5588.8 mm/day, with the highest hourly rainfall is 541.2 mm/hour

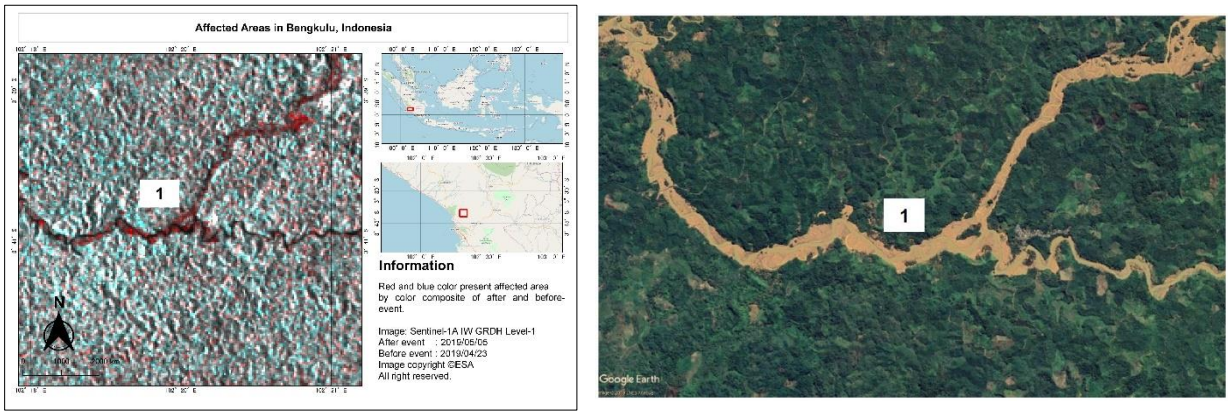
Three landslides were observed between the ARG Bukit Kaba, ARG PH Kabawetan, and ARG Rejang Lebong in Figure 1.a. The one place is ARG Bukit Kaba's cumulative rainfall information of 1236.6 mm/day with the highest hourly rainfall of 113.8 mm/hour at 24:00 April 26, 2019, or 00:00 April 27, 2019, as weighty rainfall. The second place is ARG PH Kabawetan provides cumulative rainfall information of 70.2 mm/day with the highest rainfall of 20.6 mm/hour at 14:00 April 26, 2019, as heavy rainfall. The third place is ARG Rejang Lebong, with cumulative rainfall information of 5087.4 mm/day; the highest is 524.4 mm/hour at 24:00 April 4, 2019, or 00:00 April 27, 2019, heavy rainfall.

Based on Google Imagery (May 2, 2019), Figure 1.c showed the landslide in mountainous areas due to heavy rainfall and the sediment directly transport to the river. Sediment made the Batang Simpangaur river depth shallower than average, so this is also one-factor causing flooding. After the landslide, Figure 2.b shows the river change's width affected by a sediment after the landslide, the red color present after the event in Figure 2.a.



(a) **(b)** **(c)**

Figure 1. Information of cumulative rainfall and condition of location before/after of landslide
(a) Map of cumulative rainfall from April 26, 2019 at 00.00 WIB until April 27, 2019 at 00.00 WIB;
(b) Location condition before landslide on July 23, 2018;
(c) Location condition after landslide on May 2, 2019



(a) **(b)**

Figure 2. The affected area by sediment or debris flow
(a) Analysis using RGB composite Dual-polarimetry Sentinel-1;
(b) Observation by Google Imagery provided from CNES/Airbus (2019)

(a) (b)

Figure 3. Photos of affected areas by flood
(a) The urban area affected by flood in Bengkulu (CNN Indonesia, 2019);
(b) Bridge covered by river water in Bengkulu City (Firmansyah, 2019)

CONCLUSION

The Bengkulu flood and landslide disaster with weighty rainfall in 2019 were analyzed. Floods occurred due to high rainfall on April 26, 2019. One of the rainfall observation stations, namely the ARG BP3 Tes, even providing cumulative rainfall data reaching 5588.8 mm/day with the highest hourly rainfall, is 541.2 mm/hour. Simultaneously, One of the landslides occurred between Station ARG Bukit Kaba, station ARG PH Kabawetan, and station ARG Rejang Lebong. This three-station observed heavy rainfall. Based on a Google Imagery (May 2, 2019), the landslide's location in the mountainous area and the sediment directly transport to the river; the sediment causes the Batang Simpangaur river depth shallower than average is also one of the factors causing flooding.

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