Mapping Oil Spill Using Sentinel-1: Study Case of Karawang Oil Spill

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Abstract. Indonesia as a maritime country has many challenges in developing and making innovations in the marine sector. One of the challenges for Indonesia is how to respond to oil spill disasters that occur because of various events such as blow-out on oil platforms, ship collisions, pipeline leaks, and so on. In the end, marine and coastal pollution cannot be avoided. Karawang is one of the productive northern coastal areas of Java Island with various facilities such as single point mooring, oil wells, tourist areas and historical heritage. On July 15, 2019, an oil-well belonging to Pertamina Hulu Energi (PHE) ONWJ had leaked and polluted the sea and coast not only in Karawang, but also spread to Jakarta waters. As a result of this leakage, of course the impact is very large and varied from ecological, social and economic aspects. In this paper, an oil spill mapping will be carried out to determine the affected areas using sentinel-1 data. Data processing is assisted by open-source software SNAP (Sentinel Application Platform). As the result, August 19, 2019, oil spill seen in Bekasi area. So that oil slick move from Karawang to the west. This oil spill map area can be used in many ways such as clean-up strategy, calculating amount of dispersant, and many more.

1. Introduction

The development of technology in the maritime world is currently advancing rapidly. The term blue economy which pays attention to economic value activities serving the oceans is starting to become popular and has become a trend in various countries. Pollution of the marine environment by various pollutants due to human activities is of great concern. The losses incurred are not only material, but also biological and socio-economic, which, although they can be represented in currency, still need a certain period of time to recover. Especially if we focus on coastal areas that are sensitive and have high value for both humans and other biological creatures, the impact of pollution will greatly affect the survival of both.

Coastal areas in the northern and southern parts of Java have an important role in the marine sector. There are various kinds of facilities such as ports, offshore platforms, single point mooring (SPM), ponds, recreational vehicles, and so on with high productivity and economic value. Therefore, this study will be carried out on the mapping Karawang oil spill which occurred in July 2019 in the affected coastal environment.

However, it is stated that the effects of an oil spill can be determined in several ways such as direct observations of wildlife condition (weather it was dead or dying), contrasts populations of plant and animals before and after oil spill, and modelling of the fate and transport of the oil with hydrodynamics.
software [1]. Mapping oil spill is one of the preliminary steps to further step in case of oil spill assessment.

Remote sensing in the scope of GIS (Geographical Information System) is one way to get data sources from an object or phenomenon without making direct contact. By using satellite-based imageries provide opportunities to map oil spill in large scale effectively [2]. Remote sensor system in remote sensing is divided into 2: passive sensor system and active sensor system. The use of passive sensors can actually be used, but in tropical areas such as Indonesia, active sensors are better in providing observation data that can penetrate clouds so for oil spill detection, SAR (Synthetic Aperture Radar) as is generally used. SAR (Synthetic Aperture Radar) is an active microwave sensor, which captures two dimensional images. Detecting oil spill with SAR image relies on the fact that the oil film decreases backscattering of the sea surface resulting dark spot contrasting the brightness of spill-free area [3]. The main point is after oil spill was happened in the certain area, it was captured by satellites carrying SAR instrument. The challenge in processing data using radar sensors is sea capillary waves reflect radar signals, resulting illuminated image called “sea clutter” [4]. This may cause “look-alike” phenomenon. Fingas [4] also revealed that many objects cause this phenomenon such as wave shadows, freshwater slick, biogenic oils, shallow seaweed beds, etc.

Some of the satellites that have been launched equipped with SAR instruments are SEASAT was launched in 1978 as pioneer of SAR satellite until RASARSAT was launched in 2018 by the Canadian Space Agency. These SAR satellites have bands C, L, or X. Although Marzialetti and Laneve [5] reveal that among the three bands, the X band is better than the C and L bands but the three bands generally present oil spill data well. Sentinel-1 is one of the SAR satellites owned by ESA with C bands. Sentinel-1 is not the latest SAR satellite for now, but it is still relevant to detect oil spill because one of the purposes of Sentinel-1 was to detect and map oil spill. Therefore, imagery from Sentinel-1 is widely and generally used in the development of oil spill maps. This study uses free data Sentinel-1 images and open-source software to presented aims at detecting and mapping oil spill in Karawang.

2. Study Area
The study was conducted in the northern coast of West Java, especially the district Karawang is the place most affected by the oil spill. The northern part of West Java Province is the productive Java Sea. There are so many oil wells in the area, not only that, but the Java Sea is a transportation route for ships. On July 12, 2019, gas bubbles were seen in the YYA-1 oil well, which is located about 2 kilometers from the Karawang coast. YYA-1 is Pertamina's oil platform which is located at the coordinates 6°05'650”S, 107° 37'542” E (Figure 1).

3. Materials and Method
3.1 Data Collection
All data were acquired from ASF Data Search. Sentinel-1 data level 1 Ground Range Detected (GRD) were used in this study. Datasets were acquired in both VH and VV polarisation. However, we use VV polarisation, because it displays oil spill more clearly than VH [2].

3.2 Method
Processing dataset of the SAR image using SNAP (Sentinel Application Platform), an open-source software for Sentinel created by Brockmann Consult. The algorithm that used in SNAP is adaptive thresholding.

First of all, images that chosen was the clearer and suitable one, among the other data. It is obvious to filter dataset because sentinel-1 images do not cover all over area that needed in certain time. Combining one to the other dataset is common if required. After input the image, geometric correction was used to make sure that concern area is sea surface. Next, radiometric correction refers to speckle filtering. Purpose of speckle filtering is to eliminate backscatter that ruin the quality of image. Dark spot detection guide to know where the spot assumed as oil spill. SNAP use adaptive thresholding where define oil spill area as dark spot with lower dB than average level backscatter non-oil spill area.
4. Result and Discussion
Several processes were made to know where area that affected by oil spill. Pixel values in non-oil spill area are lower than the pixels on oil spill area. In general, oil spill area would have lower pixel then appear with darker region than non-spill area. The 3 days after oil slick seen in the YYA-1, the oil rapidly approached the shore as seen in figure 4. The dB in pixel profiling seem not obvious between oil spill and non-oil spill area. As mentioned before, it is most likely the slick look-alike because of shadow from waves, slick of fresh water or other reason. However, the pixel profiling shown 4 dB differences between oil slick and non-oil area. Where non-oil area is around 17 dB and oil slick around 13 dB. This result use as adaptive thresholding to determine the oil spill area (red box). The correlation between unclear oil spill detection and profile plot is where the initial image has poor quality may cause by heavy rain or cloud, make it harder to detecting the dark spot as oil spill because it similar with surrounding, and continue to similar dB in pixel profiling.

Figure 1. Location of YYA-1 oil-well as the oil spill point-source (source: googlemaps.com)

Figure 2. Processing oil spills mapping

Figure 3. Pixel profiling of oil slick and non-polluted water (data July 21, 2019)
Second dataset that used in this study is August 19, 2019. The spill area stable in around 16 dB and non-spill area higher than that peaked at 20 dB (figure 4). Therefore, thresholding 4 dB or lower than that used to extract pixels with oil spill. Based on the results, the method that used successfully detected oil spill in 2 different time series. The similarity of dB in first and second dataset does not mean anything (differences between oil spill and non-oil spill both are around 4 dB). It does not mean that is the certain number to be fulfilled or standard to determine oil spill. The point of pixel profiling is determining the dB of oil spill and non-oil spill area, the number can be various.

From the images can be known that oil spill trajectory to the west side of the source (Karawang). Dynamic condition of sea may cause that. Whether it was currents, waves, batymethry, slope, or etc. The accuracy of SNAP’s detection oil spill itself poor enough if not collaborated with manual analysis. As seen at figure 7, the oil spill (marked with red dots) was reached Jakarta even further as result of automatic oil spill process at dataset 19 July 2019. It was stated by Pertamina, that on 19 July 2019 oil spill detected in Karawang onshore only, and predicted need several days until reached Jakarta onshore. This is disadvantages of using SAR images where look-alike phenomenon very common to happen. Once oil reached coastal area, it more difficult to analysis because of wave shadow, shallow beds, or low wind speed in that area.
Figure 7. Automatic oil spill detection may cause fault in detecting oil spill, such as red dots in the figure that stated as oil spill by SNAP but actually it is not (data 19 July 2019)

5. Conclusion
This study describes an oil spill that occurred in Karawang by using the open source software, SNAP. As a result, oil spills were detected by applying an adaptive threshold. The data used is that on August 11, 2019, oil has reached the western region of Karawang (Bekasi and its surroundings). Thus, the area affected by the oil spill also extends to these water areas. However, mapping the oil spill with Sentinel-1 has its advantages and disadvantages. It takes a validation process in the field directly to find out the extent of the impact of oil spill. Dynamic sea conditions also mean that oil spills are not perfectly mapped, because it changes due to wind, current, and waves. However, mapping the oil spill using SAR images helps as an initial step in the response to an oil spill disaster.

6. References
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