Fishing boat detection using Sentinel-1 validated with VIIRS Data

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Abstract. Detecting fishing boat activity is still a challenge for the biggest archipelago countries, such as Indonesia, to monitor the huge marine area. Space technology using sensors SAR to detect ships has been developed since 1985. However, the cost of using SAR images is one of the barriers to operational aspects, mainly for detecting fishing boats to deter IUU fishing activities. This research aims to evaluate the use of Sentinel 1-SAR imagery for identifying fishing boats from space. We used VIIRS data for validating the purposes. Both data sources could be accessed freely. The object detection process can be derived into three steps: pre-processing, object detection and object validation. We used the constant false alarm rate (CFAR) method to discriminate against objects at sea. To identify fishing vessels, we used the size of the vessels and the intensity of light captured by VIIRS. According to the findings, 21 boats were discovered using sentinel 1-SAR imagery and four boats using VIIRS data based on the the area of interest.

1. Introduction
Indonesia is the largest maritime country in the world with a water area of around 6.32 million square kilometers [1]. Monitoring of human activities at sea needs to be carried out for sovereignty, security, safety, and sustainability. One of the most important of marine monitoring is to deter the activities of Illegal Unregulated and Unreported (IUU) fishing. Indonesia is one of the countries with the highest IUU fishing activities [2]. However, monitoring the very huge marine area is still a challenge in Indonesia [3].

The role of satellite-based monitoring technology is very practical in detecting the occurrence of illegal fishing. Several technologies have been used widely for monitoring vessel activities, such as vessel monitoring system (VMS), automatic identification system (AIS), Radar-SAR imagery, very high-resolution optical imagery, and Visible Infrared Imaging Radiometer Suite (VIIRS) [4,5,6]. VMS and AIS are GPS-based monitoring technologies [7]. Ships with VMS or AIS devices transmit their positions periodically to data centers. Meanwhile, radar-SAR, optical imagery, and VIIRS are satellite imagery-based monitoring technologies. Radar-SAR based satellite use electromagnetic waves as a sensor to detect objects on the earth. As an active device, satellite Radar-SAR could capturing the object day and night as well as in any weather condition [10]. Contrarily, Optical imaging and VIIRS data both employ camera sensors as passive devices to capture objects on the earth's surface. The shortcoming of optical sensors is that the existence of clouds demonstrates the limit of their ability to detect objects.
Radar-SAR data as one source to detect IUU fishing activity has been used widely in the last decade. It is not only because of their capability to operate in all conditions, as mentioned in the paragraph above, but also because of their ability to scan huge regions. Several case studies in Indonesia [3], Ghana [10], the Flemish Cap and the North Sea [11] have been using Radar-SAR images to detect IUU fishing activity.

However, the use of satellite imagery to detect boats in operational contexts is expensive. This study was conducted to analyze the use of Sentinel 1-SAR and VIIRS data for fishing boats detection, which the data can be accessed freely.

2. Materials and method

2.1. Study Area and Data
The study area is located in the south of Central Kalimantan on the Java Sea (Figure 1.). The area is part of the 712 fisheries management area (FMA) that is one of the highest fishing activities in Indonesia.

![Figure 1. The area of interest in the study is marked with red square. (The yellow square represented the region to search the AOI on the database and the blue squares showed the results)](image.png)

We used two datasets, including Sentinel 1-SAR data and VIIRS data. Sentinel 1-SAR data and VIIRS data acquired on time-date January 6, 2021-22:16:34 and January 6, 2021-18:34:33 respectively. The Sentinel 1-SAR image was downloaded from the ASF (Alaska Satellite Facility) website (https://search.asf.alaska.edu). VIIRS data can be accessed from EOG website (https://eogdata.mines.edu/vbd/). Both datasets are provided freely with certain requirements. The characteristics of the Sentinel 1-SAR image that we processed using SNAP tool are shown in Table 1.

| No | Specifications       | Descriptions                                      |
|----|----------------------|---------------------------------------------------|
| 1  | Satellite Mission    | Sentinel 1-A                                      |
| 2  | Acquisition Mode     | IW (Interferometric Wide Swath Mode)              |
| 3  | Acquisition time     | January 6, 2021-22:16:34                          |
| 4  | Product Type/ Level  | Ground Range Detected with High Resolution (GRDH)/|
|    |                      | Level-1 (L1)                                      |
### 2.2 Methods

#### 2.2.1 Sentinel 1-SAR Boat Detection (SBD)

The SBD is the workflow to detect boats using Sentinel 1-SAR. The Sentinel Application Platform (SNAP) was utilized to analyze the Sentinel 1-SAR images in this study. SNAP is a pixel-based algorithm that uses a systematic method to identify and eliminate false alarms from sea surface objects. We used CFAR method to determine the threshold of the object that is indicate as boats or non-boats. The workflow completes of Sentinel 1-SAR in order to detect boats consist of three steps: preprocessing, object detection, and extracting boat position (Figure 2).

The pre-processing stage involves methodically adjusting the SAR picture to reduce interference such speckle noise caused by backscatter signal processing and geometric distortion caused by microwave propagation. Applying thermal noise removal, orbit file, terrain correction, remove GRD border noise, subset imagery, land sea mask and calibration, are all pre-processing sub-steps.

Thermal noise removal is used to minimize noise effects in the inter-sub-swath texture, in particular by normalizing the backscatter signal over the whole Sentinel-1 scene, resulting in fewer discontinuities between sub-swaths for scenes acquired in multi-swath acquisition modes. Applying the orbit file, we may get precise satellite location and velocity data. Terrain corrections are designed to correct for side-looking geometry distortion so that the geometric representation of the image is as similar to the real world as feasible. Remove GRD border noise was created to eliminate low-intensity noise and incorrect data at scene edges. The subset is used to clip the image so that it just focuses on the area that is being investigated. The land sea mask is used to mask out the land utilizing vector data in order to avoid erroneous target detection. Calibration is used to convert digital pixel data to radiometrically calibrated SAR backscatter.

Adaptive thresholding and object discrimination are the two phases in the object detection process. The constant false alarm rate (CFAR) is a form of adaptive thresholding method that uses SAR images to detect item distribution on the sea surface. The goal of the CFAR algorithm technique is to detect extremely bright pixels in comparison to the surrounding pixels. The final step is to extract the boat position derived from Sentinel 1-SAR.

![Figure 2. Flow Diagram for Ship Detection Using Sentinel 1-SAR.](image-url)
2.2.2 VIIRS Boat Detection (VBD).
The VBD is a method for detecting fishing boats at night based on light intensity [8]. In this study, the VBD data was generated using the algorithm described by Elvidge et al. [9]. The VBD data was produced by the EOG in CSV and KMZ files, which could be accessed in near real time [7].

2.2.3 Cross Matching
We developed the workflow to cross-match the Sentinel-1 based SBD and the VIIRS based VBD as shown in Figure 3. The timing of satellite overpass must be known in order to match SBD to VBD data. We select the closest satellite overpass time for a certain time and area for both sources of data. We extract the data (position and time) from SBD and VBD data and convert them to SHP files for displaying on the GIS desktop.

3. Results and Discussion

3.1 Boats Detection
Boats distribution detected from Sentinel 1-SAR imagery shown in Figure 4. From Sentinel 1-SAR images, 21 boats have been identified (Figure 4). Meanwhile, data from the VIIRS has shown the presence of four boats (Figure 5). In general, the Sentinel 1-SAR sensor detects more boats than the VIIRS sensor, since the radar-SAR sensor identifies all sorts of vessels within a specified length, but the VIIRS sensor only lights fishing boats. Thus, by combining the data distribution of vessels generated from the Radar-SAR sensor with the distribution of fishing boats derived from the VIIRS sensor will likely be utilized to discriminate fishing boats.

3.2 GIS Based Cross Matching Analysis
Here we overlay the distribution of boats using a GIS application. In this study, VIIRS identified 19% of the boats when compared to the Sentinel 1-SAR image. The result of the cross-matching between boats derived from Sentinel 1-SAR (red circles) imagery and VIIRS data (green circles) is shown in Figure 6. The yellow lines shown in Figure 6 were the nearest matches. The match distance between both objects is approximately 7 km.

Several factors contribute to the difference in distance and in the number of boats detected:
- The difference in data acquisition time is 4 hours 18 minutes.
- VIIRS data only detects boats with night light radiances that correspond to fishing boats, while Sentinel 1-SAR data detects all types of boats.

Figure 3. Cross Matching Sentinel 1-SAR with VIIRS Data
3.3 Practical perspective.

We demonstrated in this study that Sentinel 1-SAR imagery could be used to identify boats using the CFAR method, which was analyzed using the SNAP platform. However, for validation purposes and to distinguish the type of vessel detected as a fishing boat, we need other sources of data. The correlating VMS and AIS data have been widely used for validating boats as objects derived from SAR imagery data [12, 13]. On the other hand, using VMS data or AIS data to correlate with SAR imagery has limitations. The transmitter devices could be turned off or covered with a metal cage in order to block radio waves. To deal with it, here we used VIIRS data to match with SAR imagery in order to validate the existence of a fishing boat in the area of interest. Although the boats are not activating the VMS or AIS devices, we are likely to detect the fishing boats indicated by the VIIRS data.

Figure 4. Boats distribution detected from Sentinel 1-SAR imagery are marked with red circles.

Figure 5. Boats distribution detected from VIIRS data.
4. Conclusion

The detection and the validation of fishing boats from space are still a challenge in maritime domain awareness. Sentinel 1–SAR imagery and VIIRS data could be utilized to detect fishing boats. The light of fishing boats on the open sea at night is detected by VIIRS data, but the presence of clouds limits detection. The Sentinel-1 SAR data, on the other hand, identifies boats on the water even through clouds. In this preliminary study, due to the gap in collection time, the efficacy of cross-matching Sentinel-1 and VIIRS data for validation purposes is poor. We discovered 21 boats in one scene of the Sentinel 1-SAR image, but only four boats in the same area with near temporal time utilizing VIIRS data.

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