

FISHING-VESSEL DETECTION USING SYNTHETIC APERTURE RADAR (SAR) SENTINEL-1 (CASE STUDY: JAVA SEA)

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Abstract. The synthetic aperture radar (SAR) instrument of Sentinel-1 is a remote sensing technology being developed to enable the detection of vessel distribution. The purpose of this research is to study fishing-vessel detection using SAR Sentinel-1 data. In this study, the constant false alarm rate method (CFAR) for Sentinel-1 data is used for the detection of fishing vessels in Indramayu sea waters. The data used to detect ships includes SAR Sentinel-1A images and vessel monitoring system (VMS) data acquired on 8 March and 20 March 2018. SAR Sentinel-1 imagery data is obtained through pre-processing and object identification using Sentinel Application Platform (SNAP) software. Overlay analysis is then used to enable discrimination of immovable and movable objects and validation of ships detected from SAR Sentinel-1 imagery is performed using VMS data. From overlay analysis, 46 ships were detected on 8 March 2018 and 39 ships on 20 March 2018. Of all the ship points detected using SAR Sentinel-1, 7.06% could be detected by VMS data while 92.94% could not. The number of ships detected by SAR Sentinel-1 is greater than those detected by VMS because not all ships use VMS devices.

Keywords: *Fishing vessels detection, synthetic aperture radar (SAR), Sentinel-1, Java Sea, vessel monitoring system (VMS)*

1 INTRODUCTION

The fisheries management area of the Republic of Indonesia (WPPNRI) 712 is a strategic fishing area with extensive maritime activity. According to KEPMENKP (2016), the estimation of potential fisheries resources in WPPNRI 712 is 981,680 tonnes/year. The high level of fishing-vessel activity on the Java Sea has obliged the government to monitor the distribution of ships to support efforts related to security, safety and fisheries sustainability. In addition, ship surveillance can also reduce illegal, unreported and unregulated fishing activities which can have negative impacts such as conflict between fishermen, decrease in state revenues

and reduction in the availability of marine and fisheries resources (Suniada, 2018).

Currently, ship monitoring in Indonesia seas is carried out by ship patrols and the use of tracking devices such as the vessel monitoring system (VMS) and the automatic identification system (AIS). The VMS and AIS systems are used to monitor the movement of vessels and provide information about ship position, speed and direction of destination to port. Both of these sources of data are used to track the existence of ships as long as the data sent by them can be received by receiver stations (Hartono, 2007; Saputra, Budi, Istardi, & Wiranto, 2016). However,

fishing-vessel monitoring in Indonesia is constrained by issues such budget limits and size of monitoring area.

One of the remote sensing satellite technologies that is currently being developed and is expected to be able to detect fishing-vessel distribution is synthetic aperture radar (SAR). This form of radar uses the electromagnetic wave spectrum in frequency range 0.3 GHz to 300 GHz, or wavelengths from 1 cm to 1 m. These microwaves are longer than the visible waves used by optical satellites and so their ability to penetrate clouds is greater and can operate during both day and night (Chulafak, Kushardono, & Zylshal, 2017). Moreover, SAR can monitor the earth's surface on a regional and a global scale (Agustan & Agustino, 2014).

Sentinel-1 is a radar satellite managed by the European Space Agency (ESA). The advantages of this satellite are the open and free policy of the European Union Copernicus programme, its medium-high spatial resolution, and temporal resolution of data access that is relatively fast compared to other radars (Grover, Kumar, & Kumar, 2018). SAR Sentinel-1 radar is used widely in a variety of fields, including oceanography, glaciology, forestry, topography, etc. It is also useful in monitoring maritime activities such as ship detection and oil spills (Pelich, Longepe, Mercier, Hajduch, & Garello, 2015; Chaturvedi, Banerjee, & Lele, 2019).

The information provided by the SAR Sentinel-1 radar can complement AIS and VMS data. Some studies, such as the research of Park et al. (2018) on the South Korean peninsula and Negula, Poenaru, Olteanu, and Badea (2016) on the River Danube, show that tracking and SAR devices have been linked in maritime applications. Information

obtained from tracking devices can be used as an evaluation or validation tool for vessel-detection results from SAR images.

SAR usage for maritime surveillance has been increasing in some countries, but in Indonesia it is still rare because it is relatively new and human resources skilled in the technology are limited. Further research into ship detection using SAR Sentinel-1 remote sensing technology to support safety and surveillance in the Indonesian sea is therefore needed.

The purpose of this research is to study the method of fishing-vessel detection using SAR Sentinel-1 data. The territory covered by the Republic of Indonesia Fisheries Management (WPPNRI) 712 in the Indramayu waters of the Java Sea is used as the location for this study because it is the territory that contributes most to the largest of the country's fishery activities, namely 60% of the total production of West Java province (KKP, 2013). Thus, the existence of fishing vessels in the area can represent the operation of fishing vessels in the Java Sea.

2 MATERIALS AND METHODOLOGY

2.1 Location and data

The study area is located in Indramayu waters, West Java (see Figure (2.1).

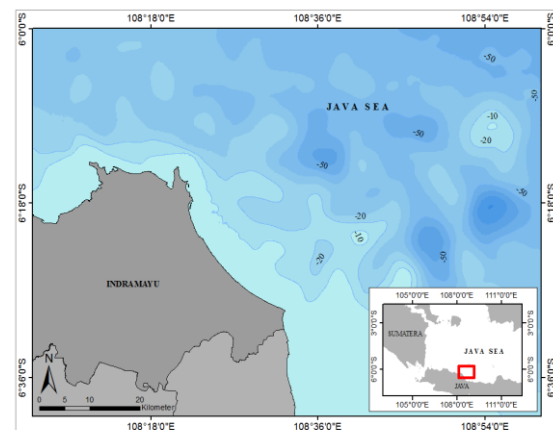


Figure 2- 2: Study area in Indramayu waters

Table 2-1: The detailed overview of the SAR Sentinel-1 imagery on 8 March and 20 March 2018

No	Characteristic	Data 1	Data 2
1	<i>Mission</i>	Sentinel-1A	Sentinel-1A
2	<i>Acquisition date</i>	8 March 2018	20 March 2018
		11:06:41 s/d 11:07:06	11:06:41 s/d 11:07:06
3	<i>Mode</i>	<i>IW</i>	<i>IW</i>
4	<i>Pass direction</i>	<i>Ascending</i>	<i>Ascending</i>
5	<i>Spatial resolution</i>	5 x 20 m	5 x 20 m
6	<i>Swath width</i>	250 km	250 km
7	<i>Polarization</i>	VH, VV	VH, VV
8	<i>Product level</i>	L1	L1
9	<i>Product type</i>	GRD	GRD
10	<i>Instrument name</i>	<i>Synthetic Aperture Radar (C-band)</i>	<i>Synthetic Aperture Radar (C-band)</i>

The data used includes SAR Sentinel-1A level 1 ground range detected high-resolution (GRDH) data acquired on 8 March and 20 March 2018 with interferometric wide swath (IW) mode and vertical-horizontal (VH) polarization. Level 1 GRD data denotes that the data have been projected using an ellipsoid earth-modelling approach (ESA, 2014). Table 2.1 gives a detailed overview of the SAR Sentinel-1 imagery used in this study.

2.2 Methods

The data processing consists of pre-processing, object identification, overlay analysis and fishing -vessel validation.

2.2.1 Pre-processing

The pre-processing step is carried out by systematically correcting the SAR image to minimize interference such as speckle noise due to the impact of backscatter signal process and

geometric distortion from microwave propagation (Bioresita, Pribadi, & Firdaus, 2018). Pre-processing sub-steps consist of applying the orbit file, calibration, speckle filtering, range doppler terrain correction, and subset imagery.

Applying the orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. Radiometric calibration is used to alter the digital number (DN) to the backscatter coefficient in the form of sigma nought (σ_0). This step is necessary for SAR images so that the pixel values of the images truly represent the radar backscatter of the reflecting surface. SAR images have inherent salt-and-pepper-like texturing called speckles which degrade the quality of the image and make interpretation more difficult. Speckle filtering is used to reduce the speckle-noise effects on the SAR image.

Both SAR images (Data 1 and Data 2) are analysed with no filter and with LEE filter with a 3 x 3 window size. The topographical variations of a scene and the tilt of the satellite sensor cause distances to be distorted in SAR images. Range doppler terrain corrections are intended to compensate for these distortions so that the geometric representation of the image will be as close as possible to the real condition. The process of range doppler terrain correction uses the availability of orbit data, acquisition process time, tilt-to-surface distances and Digital Elevation Model (DEM) references to obtain precise location (Septiana, Wijaya, & Suprayogi, 2017). The last pre-processing step is subset imaging to focus on the area that will be examined, resulting in an astronomical position of 5° 26' 02" LS – 6° 38' 51" LS and 107° 59' 00 " BT – 109° 24' 18" BT.

2.2.2 Object identification

There are three steps in the object detection operation: land-sea masking, pre-screening and object discrimination. The first step is masking the area of interest to avoid false target detection using vector data (.shp). The second step, pre-screening, is the most important step in image identification. Constant false alarm rate (CFAR) is the specific type of adaptive thresholding algorithm used in the Sentinel Application Platform (SNAP) ocean object detection tools to detect object distribution on the sea surface using SAR imagery (Serco Italia SPA, 2018). The idea of the CFAR algorithm method is to find extraordinarily bright pixels compared to the other pixels that surround the area (Bioresita et al., 2018). The detection formula of CFAR is

expressed in Equation 2-1 (Crisp, 2004).

$$x_t > T \Leftrightarrow TARGET \tag{2-1}$$

where x_t is the pixel under test and T is a given threshold. The probability of false alarm (PFA) is then given by

$$PFA = \int_T^{\infty} f(x)dx ; \tag{2-2}$$

$$\int_{x_t}^{\infty} f(x)dx < PFA \Leftrightarrow TARGET$$

where $f(x)$ is ocean clutter probability density function and x is range through the possible pixel values.

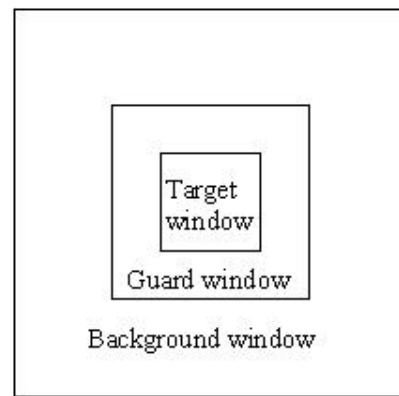


Figure 2- 3: Window setup for adaptive thresholding algorithm

If the pixel value is larger than the threshold number, the pixel will be classified as a target pixel or an identified object. For each pixel under test, there are three windows, namely the target window, guard window and background window (see Figure 2-3). The target window size should be approximately the smallest size of the detected object, the guard window size should be about the size of the largest object, and the background window size should be large enough to accurately estimate local statistics.

The next step is object

discrimination. During this operation, wrong detections are eliminated based on simple target measurements. In this study, 25 metres and 150 metres are used for minimum and maximum target size. Based on these size limits as discriminatory criteria, targets that have larger or smaller sizes will be eliminated.

2.2.3 Analysis

Image overlay is carried out to analyse the distribution of movable objects that may be ships and immovable objects. The Red, Green Blue (RGB) composite is processed using both of the sigma₀ SAR Sentinel-1 images with VH and VV polarization. The SAR Sentinel-1 imagery acquired on 8 March 2018 with VH polarization is used for red bands, sigma₀ product with VH polarization acquired on 20 March 2018 is used for green bands, and sigma₀ product with VV and VH polarization acquired on 20 March 2018 is used for the blue bands. The synthesis process of RGB bands (VH; VH; VV/VH) on both images will result in a yellow pixel group that indicates immovable objects, while the red and green pixel groups indicate movable objects.

2.2.4 Fishing-vessel validation

Validation is used to determine the type of detected ships; that is, whether they are fishing vessels or not. The VMS data is sorted according to both image acquisitions. The point of VMS data used as a reference is set at 06.00 pm to 06.59 pm, which covers the time of acquisition of the SAR Sentinel-1 images (06.06 pm – 06.07 pm). With a limit of 3,300 metres distance, (obtained from the average calculation of the vessel-point distance detected by the SAR Sentinel-1 images), VMS data, and the speed of fishing vessels, fishing-vessel distribution that is detected on SAR

Sentinel-1 images can be identified. The distance restriction by calculating radius was acquired by considering the fundamental feature of SAR imaging of target location being displaced by several hundred metres in the azimuth direction in images if targets are moving (Park et al., 2018)

3 RESULTS AND DISCUSSION

3.1 SAR Sentinel-1 image conditions at different acquisition times

The processing of SAR Sentinel-1 images begins with the pre-processing step (taking approximately one hour on a computer with specifications of 8 GB RAM, Windows 10 Home operating system 64-bit, Processor Core i5 with a speed of 2.40 GHz). The different conditions in the two SAR images are shown in Figures 3-1 A and B.

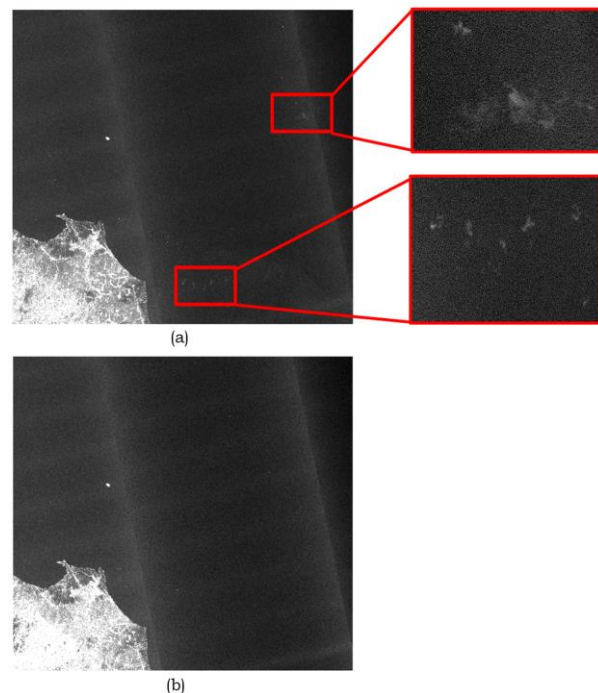


Figure 3-1: Different conditions in the two SAR images on (a) 8 March 2018 and (b) 20 March 2018

On 8 March 2018, the image is slightly disturbed due to noise at the bottom and upper right, as indicated by the red rectangular symbol, while on 20 March 2018 the the image was clean of noise. In general, the radar has good

cloud-penetrating capability compared to optical satellite imagery, but in some cases, very thick cloud cover will still affect the image-recording results. The interference found in the SAR image on 8 March may have been caused by thick cloud cover in the study area, as shown in the Himawari satellite weather conditions coverage shown in Figure 3-2.

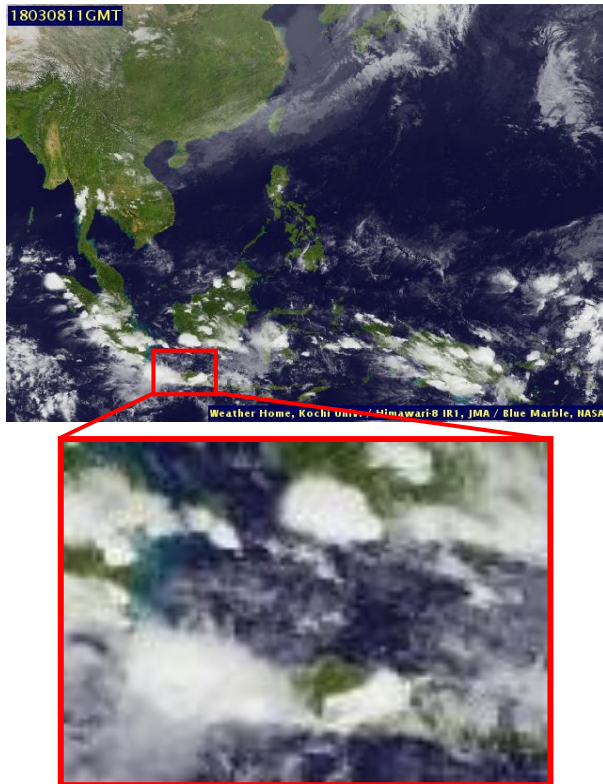


Figure 3-2: Cloud coverage at the study area on 8 March 2018

According to Alpers, Zhang, Mouch, Zeng and Chan (2016), very thick cloud conditions and high-intensity rain can affect the quality of SAR images, in that rain can cause roughening of the surface of the sea that can be recorded by the radar. This study also used VH polarization sent vertically then received again horizontally. According to Pelich et al. (2015), VH polarization has better ship detection capability than VV polarization, because VV polarization

allows many speckle-noise detections that can affect vessel-detection results.

3.2 Object identification

The detected objects on the SAR Sentinel-1 images for 8 March and 20 March 2018 with and without LEE filter are shown in Table 3-1. The number of detected objects using the LEE filter, at 255 objects on 8 March and 170 objects on 20 March, is higher than the number detected without filtering. The high number of detected objects using the LEE filter reflects its ability to maintain image sharpness and detail while suppressing noise (Haqie, 2013).

Table 3-2: The number of detected objects on 8 March and 20 March 2018

Acquisition date	Without filter	With LEE filter
8 March 2018	195	255
20 March 2018	162	170

Based on the results of DN conversion into backscatter values, the backscatter values for detected objects range from -6.18 dB to 6.15 dB, whereas the backscatter values for water range from -43.18 dB to -21.60 dB.

According to Moreira (2013), backscatter values of more than -5 dB are included in the scenario types of man-made objects, slopes, very rough surfaces and steep surface. Pixel groups on the SAR image that fulfil the CFAR criteria will be detected as objects, but in certain conditions, such as the presence of noise in the image, errors in object detection, or 'false alarms', may occur. A false alarm is an erroneous object detection caused by noise or signal interference that exceeds the detection threshold.

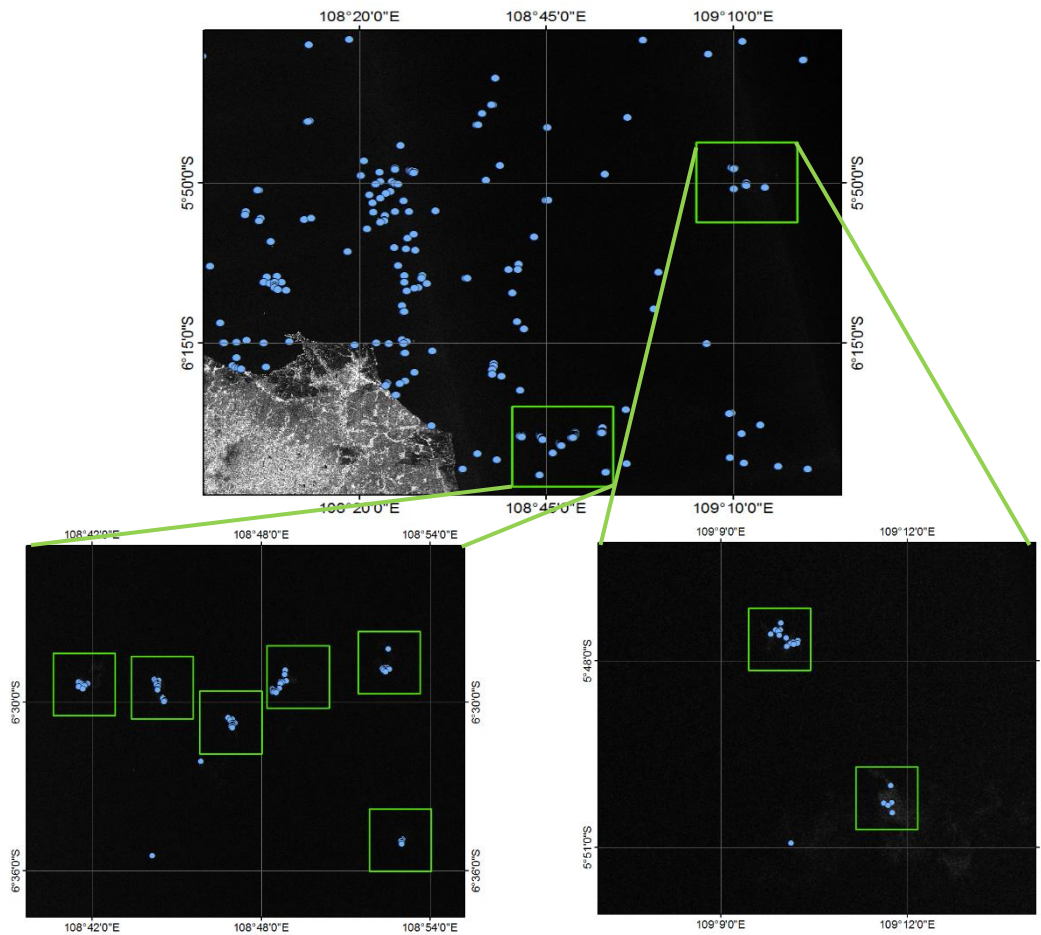


Figure 3-3: The distribution of false alarms (green) on 8 March 2018

The false alarm occurs when the detection process is not present the echo signal but a high interference signal, resulting in a statistical test value greater than the specified threshold (Ramadhan, Arseno, & Suratman, 2018).

It is necessary to calculate the number of false alarms in order to find wrongly detected objects, and this can be calculated from the backscatter value and visual observation. The backscatter value for false alarms ranges from -21.60 dB to -15.43 dB, and their distribution estimation can be seen in Figure 3-3. The result of false alarm calculation for this study is 34.5%.

3.3 Object analysis

Identification of immovable objects is shown in the yellow pixel group as a result of the overlay process of the red

pixel group for movable objects on 8 March 2018 and the green pixel group for movable objects on 20 March 2018 (See Figure 3-4). Ship distribution identified is 46 objects on 8 March 2018 and 39 objects on 20 March 2018.

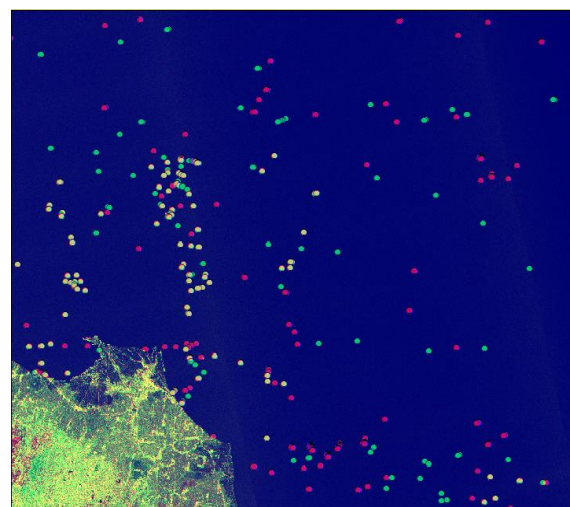


Figure 3-4: Object distribution on SAR images for 8 March 2018 (red) and 20 March 2018 (green)

3.4 Fishing-vessel validation

The validation results for ship point distribution and VMS data are adjusted to the date and time of SAR image acquisition (see Figures 3-5 A and B). The time used for VMS data to enable ship tracking in the area of study was 12.00 am to 11.59 pm. Ship points obtained from the SAR Sentinel-1 images are marked by orange circles, while the VMS points between 06.00 pm to 06.59 pm are marked by green squares.

Five points from the 8 March image and one point from 20 March 2018 are identified as fishing vessels. The closest distance validated between ship and VMS point of 21 metres, is found in the SAR image for 8 March 2018, while the farthest distance validated of 3,266 metres is in the SAR image for 20 March 2018.

A ship is a dynamic object on the sea that can move freely, either because of the physical action of the sea or the mechanical power generated by the ship itself. During the acquisition of the SAR

images, at 06.06 pm to 06.07 pm, 46 ships were detected on 8 March 2018 and 39 ships were detected on 20 March 2018. In addition, exactly at the recording time there were no ships transmitting data to receivers for these ship positions, so it can be assumed that the ship points and VMS points were not in fact in the same position. To check whether the detected ships are fishing vessels or not, it can be seen from the ships shown with a green rectangle symbol in Figure 3-4 that there were five fishing vessels on 8 March and one on 20 March 2018 that were approaching the symbol.

Out of the ships detected by SAR Sentinel-1, 7.06% were detected by VMS, while 92.94% were undetected. The ship points that were not detected by VMS data results from lack of VMS devices on the fishing vessels, because installation of these devices is only required for fishing vessels with ≥ 30 gross tonnage (GT) loads (Muhammad, Paroka, Rahman, & Syarifuddin, 2018).

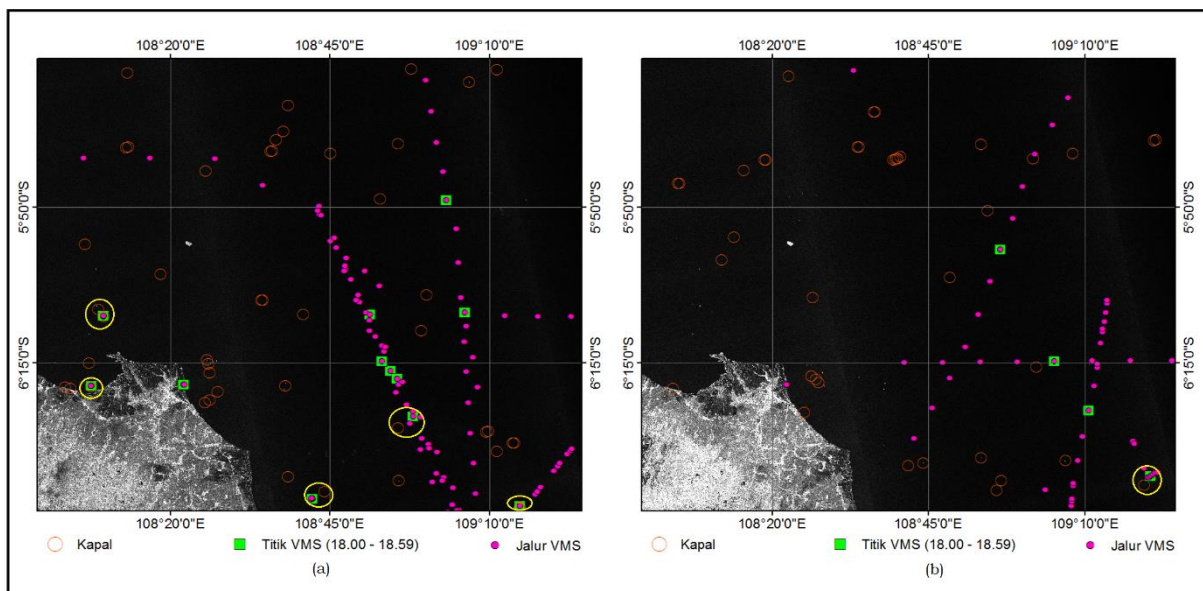


Figure 3- 5: Validation of ship distribution detected by SAR Sentinel-1 and VMS data on 8 March 2018 (a) and 20 March 2018 (b)

Ships with 30 GT loads do not always having lengths of more than 25 metres, because GT measurements are calculated from the volume of space under the deck together with covered deck (Sa'dana, Amiruddin, & Santosa, 2017). For example, the analysis of 30 GT traditional purse seiner fishing vessels by Mulyatno, Jatmiko, & Susilo (2012) revealed approximate length 17.5 metres. Thus, unidentified ship points and VMS points can be caused by vessels of less than 25 metres being eliminated at the object discrimination stage due to a minimum object limitation size of 25 metres.

4 CONCLUSION

Based on the results of this study it can be concluded that a fishing-vessel detection method using SAR Sentinel-1 data has been identified. The method used in this study was CFAR, which can detect the pixels representing fishing vessels automatically by comparing extraordinarily bright pixels with other pixels surrounding them. By using the CFAR method, the size of target window can be adjusted to pixel size and the actual size of fishing vessels. Thus, monitoring of fishing vessels can be carried out accurately.

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AUTHOR CONTRIBUTIONS

Fishing-Vessel Detection using Synthetic Aperture Radar (SAR) Sentinel-1 (Case Study: Java Sea). Lead Author: Sarah Putri Fitriani; Co-Author: Jonson Lumban Gaol and Dony Kushardono

REFERENCES

- Agustan, A., & Agustino, R. S. (2014). Ship detection based on synthetic aperture radar technique. *Indonesian Journal of Geospatial*, 4(1), 10–19.
- Alpers, W., Zhang, B., Mouche, A., Zeng, K., & Chan, P. W. (2016). Rain footprints on C-band synthetic aperture radar images of the ocean – revisited. *Remote Sensing of Environment*, 187, 169–185. doi:10.1016/j.rse.2016.10.015
- Bioresita, F., Pribadi, C. B., & Firdaus, H. S. (2018). Ship detection in Madura Strait and Lamong Gulf using Sentinel-1 SAR data. In: Mustika IW, Kartini I (Eds). *Proceeding of The 3rd International Conference on Science and Technology*, pp. 13–23. doi: 10.29037/digitalpress.11224
- Chaturvedi, S. K., S. (2019). An assessment of oil spill detection using Sentinel-1 SAR-C images. *Journal of Ocean Engineering and Science*. doi: 10.1016/j.joes.2019.09.004
- Chulafak, G. A., Kushardono, D., & Zylshal, Z. (2017). Optimasi parameter dalam klasifikasi spasial penutup penggunaan lahan menggunakan data Sentinel SAR [Parameter optimization in spatial closing classification of land use using SAR Sentinel data]. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital*, 14(2), 111–129, doi: 10.30536/j.pjpdcd.1017.v14.a2746
- Crisp, D. J. (2004). *The State-of-the-Art in Ship Detection in Synthetic Aperture Radar Imagery*. Edinburgh (AU): Australian Government, Department of Defence.
- ESA. 2014. Technical guides of Sentinel-1 SAR. Available at: <https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar/products-algorithms/level-1-algorithms/ground-range-detected>
- Grover, A., Kumar, S., & Kumar, A. (2018). Ship detection using Sentinel-1 SAR data. In: Kumar, A. S., Saran, S., & Padalia, H. (Eds). *ISPRS TC V Mid-term Symposium "Geospatial Technology – Pixel to People"*

- in *International Society for Photogrammetry and Remote Sensing* (pp. 317–324). doi: 10.5194/isprs-annals-IV-5-317-2018
- Haqie, D. (2013). *Pemrosesan citra Alos Palsar level 1.1 untuk identifikasi tutupan lahan wilayah kota Semarang, Jawa Tengah [Alos Palsar level 1.1 image processing for identification of land cover in the city area of Semarang, Central Java]*. Undergraduate thesis, Universitas Gadjah Mada, Indonesia.
- Hartono, B. D. (2007). *Analisis model Vessel Monitoring System (VMS) dalam pengawasan kapal penangkap ikan di Indonesia [Analysis of the Vessel Monitoring System (VMS) model in the supervision of fishing vessels in Indonesia]*. Dissertation, Institut Pertanian Bogor, Indonesia.
- KEPMENKP (2016). Keputusan Menteri Kelautan dan Perikanan Nomor 47 Tahun 2016 tentang Estimasi Potensi, Jumlah Tangkapan yang Diperbolehkan, dan Tingkat Pemanfaatan Sumber Daya Ikan di Wilayah Pengelolaan Perikanan Negara Republik Indonesia [Decree of the Minister of Maritime Affairs and Fisheries 47, 2016, concerning estimation of potential, number of catches permitted, and level of utilization of fish resources in the territory of the Republic of Indonesia, Fisheries Management].
- KKP (2013). Profil Kelautan dan Perikanan Provinsi Jawa Barat untuk Mendukung Industrialisasi KP. Pusat Data Statistik dan Informasi Sekretariat Jenderal Kementerian Kelautan dan Perikanan [Marine and fisheries profile in West Java to support KP industrialization, Statistics and Information data center of the Secretariat General of the Minister of Maritime Affairs].
- Moreira, A. (2013). Synthetic Aperture Radar (SAR): Principles and application. *The 4th Advance Training Course in Land Remote Sensing*, 2013 1–5 July, Athens, Greece.
- Muhammad, A. H., Paroka, D., Rahman, S., & Syarifuddin. (2018). Tingkat kelayakan operasional kapal perikanan 30 GT pada perairan Sulawesi (studi kasus KM Inka Mina 957) [Operational feasibility level of 30 GT fishing vessels in Sulawesi waters (KM Inka Mina 957KEPMENKP case study)]. *Marine Fisheries*, 9(1), 1–9. doi: 10.29244/jmf.9.1.1-9
- Mulyatno, I. P., Jatmiko, S., & Susilo, F. (2012). Analisa investasi kapal ikan tradisional purseiner 30 GT [Investment analysis of traditional 30 GT purse seiner fishing vessels]. *KAPAL: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan*, 9(2), 58–67. doi: 10.14710/kpl.v9i2.4390
- Negula, D., Poenaru, V. D., Olteanu, V. G., & Badea, A. (2016). Sentinel-1/2 data for ship traffic monitoring on the Danube River. In Halounova, L., et al. (Eds). *XXIII ISPRS Congress, Commission VIII in International Society for Photogrammetry and Remote Sensing* (pp. 37–41). doi: 10.5194/isprarchives-XLI-B8-37-2016
- Park, K. A., Park, J. J., Jang, J. C., Lee, J. H., Oh, S., & Lee, M. (2018). Multi-spectral ship detection using optical, hyperspectral, and microwave SAR remote sensing data in coastal regions. *Sustainability*, 10(4064), 1–23. doi: 10.3390/su10114064
- Pelich, R., Longepe, N., Mercier, G., Hajduch, G., & Garello, R. (2015). Performance evaluation of Sentinel-1 data in SAR ship detection. *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)* (pp. 2103–2106). doi: 10.1109/IGARSS.2015.7326217
- Ramadhan, F., Arseno, D., & Suratman, F. Y. (2018). Deteksi sinyal target dengan menggunakan metode algoritma Constant False Alarm Rate (CFAR) pada search radar [Detecting target signal using the Constant False Alarm Rate (CFAR) algorithm on radar search]. *E-Proceedings of Engineering*, 5(3), 4722–4729.

- Sa'dana, B., Amiruddin, W., & Santosa, A. W. B. (2017). Analisa teknik dan ekonomis modifikasi desain lambung kapal ikan tradisional 30 GT tipe batang [Technical and economic analysis of the modification of the traditional 30 GT type hull fishing rod design]. *Jurnal Teknik Perkapalan*, 5(4), 602–611.
- Saputra, H., Budi, K. A. A., Istaridi, D., & Wiranto, S. S. (2016). Penggunaan data *Automatic Identification System* (AIS) untuk mengetahui pergerakan kapal (studi kasus pada lalu lintas kapal di selat Singapura dan perairan Batam) [Use of Automatic Identification System (AIS) data to determine vessel movements (case study on ship traffic in the Singapore strait and Batam waters)]. *Jurnal Integrasi*, 8(2), 139–143.
- Septiana, B., Wijaya, A. P., & Suprayogi, A. (2017). Analisis perbandingan hasil orthorektifikasi metode range doppler terrain correction dan metode SAR simulation terrain correction menggunakan data SAR Sentinel-1 [Comparative analysis of orthorectification results of the range doppler terrain correction method and the SAR simulation terrain correction method using Sentinel-1 SAR data]. *Jurnal Geodesi Undip*, 6(1), 148–157.
- Serco Italia SPA. (2018). Ship detection with Sentinel-1 – Gulf of Trieste (version 1.3). Retrieved from <https://rus-copernicus.eu/portal/the-rus-library/learn-by-yourself/>
- Suniada, K. I. (2018). Validasi sebaran kapal penangkap ikan tradisional menggunakan data penginderaan jauh dan GPS tracker [Validating the distribution of traditional fishing vessels using remote sensing data and GPS tracker]. *Journal of Marine and Aquatic Sciences*, 4(1), 14–21, doi:10.24843/jmas.2018.v4.i01.14-21.

