ABSTRAK

Selat Makassar merupakan bagian Alur Kepulauan Laut Indonesia (ALKI) dan dikenal dengan lalu lintas laut yang cukup padat. Kondisi tersebut membawa ancaman tumpahan minyak bagi ekosistem laut. Tumpahan minyak dapat berasal dari operasi rutinitas kapal maupun dari infrastruktur tambang minyak bumi. Oleh karena itu, pengawasan tumpahan minyak merupakan pekerjaan yang sangat penting. Deteksi keberadaan tumpahan minyak melalui satelit penginderaan jauh (inderaja) merupakan metode yang efektif dan efisien dari segi biaya dibandingkan teknik konvensional yang melibatkan survei lapangan. Tesis ini bertujuan untuk memanfaatkan citra radar Sentinel-1 untuk mendeteksi tumpahan minyak di Selat Makassar. Namun, deteksi tumpahan minyak pada citra radar memiliki tantangan utama dengan keberadaan *look-alike* atau objek yang mirip tumpahan minyak. Oleh karena itu, penelitian ini juga memanfaatkan data tambahan terkait kondisi atmosfer dan oceanografi seperti kecepatan angin, klorofil-A, suhu permukaan laut dan tingkat presipitasi untuk membedakan tumpahan minyak dan *look-alike.* Selain itu, data kecepatan arus permukaan juga dilibatkan untuk analisis evolusi pergerakan tumpahan minyak.

Deteksi tumpahan minyak dilakukan dengan teknik interpretasi visual dan juga pengolahan citra digital. Interpretasi visual dilakukan pada citra radar yang disampel perbulan di Selat Makassar untuk mendeteksi kandidat tumpahan minyak. Interpretasi visual didasari warna dan bentuk umum tumpahan minyak yang telah dijelaskan di beberapa studi literatur. Setelah itu, dilakukan proses identifikasi hasil nterpretasi visual untuk membedakan tumpahan minyak dan *look-alike* dengan menggunakan data tambahan yang telah disebutkan. Data kecepatan angin diperoleh dari proses inversi *backscatter* citra radar, sementara data tambahan lainnya diperoleh dari produk Aqua-MODIS dan ERA5. Penelitian sebelumnya menyatakan bahwa tumpahan minyak dapat dideteksi di citra radar pada kecepatan angin 2 – 14 m/s. Langkah terakhir adalah proses pengolahan citra digital yang melibatkan tahap penajaman citra dan klasifikasi terbimbing dengan klasifikasi *Support Vector Machine* (SVM). Dari hasil klasifikasi tersebut, luasan sebaran minyak dihitung. Selain itu, pergerakan tumpahan minyak juga dianalisis berdasarkan data arus permukaan.

Penelitian ini telah berhasil melakukan deteksi tumpahan minyak di Selat Makassar pada tahun 2018. Berdasarkan hasil interpretasi visual, tumpahan minyak berbentuk *tail* dan *angular winding* paling sering dijumpai. Hal ini mengindikasikan bahwa tumpahan minyak di area penelitian didominasi dari kapal dan infrastruktur tambang minyak bumi. Sementara itu, hujan merupakan fenomena yang paling sering dijumpai sebagai *look-alike,* diikuti pula dengan ledakan alga yang lebih jarang terjadi. Dari hasil pengolahan citra digital, diketahui bahwa tekstur dengan kombinasi korelasi, (korelasi/entropi) dan *angular second moment* (ASM) merupakan kombinasi RGB yang tepat untuk kasus penelitian ini. Selain itu, tumpahan minyak di Selat Makassar tahun 2018 diestimasi mencapai 45.402,31 Ha.

Kata kunci: tumpahan minyak, look-alike, Sentinel-1, angin, analisis tekstur

ABSTRACT

Makassar Strait as part of Alur Laut Kepulauan Indonesia (ALKI) or Indonesian Archipelagic Sea Lane is known for its high density of marine traffic. High density of marine traffic can pose serious threat for the marine ecosystem and also the community along the coast in term of oil spill. Oil spill may originate from ships or offshore-oil platforms. Hence, oil spill monitoring is an essential task as mean to reduce oil spill on the ocean. Oil spill monitoring through remote sensing satellites provides more effective and cost-efficient method compared to the traditional technique which involves ship and airborne survey. This study aims to utilise remotely-sensed data, especially Synthetic Aperture Radar (SAR) image from Sentinel-1 mission for oil spill monitoring in Makassar Strait. However, oil spill monitoring on SAR has a major challenge where the presence of objects looking similar to oil spill, called look-alike, can lead to misclassification. Thus, this study also includes other auxiliary oceanic and atmospheric data such as wind speed, chlorophyll-A concentration, sea surface temperature (SST) and precipitation rate to assist oil spill and look-alike discrimination. In addition, ocean surface current was also used to study the movement of oil spill spread on the ocean.

Oil spill monitoring was carried out using both manual inspection and digital image processing. Multi-temporal manual inspection on monthly-sampled SAR images was initially performed in search of dark formations as probable oil spills. Manual inspection was based on the common characteristics of oil spill's colour and shape on SAR image reported on many previous studies. Next, oil spill and look-alike discrimination were done using wind speed, SST, chlorophyll-A and precipitation rate. Wind speed was retrieved from SAR backscatter using geophysical model provided by Sentinel Application Platform (SNAP), while other auxilary data were from Aqua-MODIS and ERA5. Studies have reported that oil spills were optimally detected on SAR image in the wind speed between 2 to 14 m/s. Lastly, digital image processing was carried out which included SAR pre-processing, texture analysis as image enhancement task, and Support Vector Machine (SVM) supervised classification. Based on the classification results, oil spill spread analysis was done to calculate oil spill area. In addition, oil spill movement analysis was also made using ocean surface current.

This study has successfully detected oil spills over Makassar Strait in 2018. Based on manual inspection on SAR image of oil spill's shapes which were observed as angular winding and tail-shaped oil spills, it is found that oil spills in Makassar Strait likely originated from ships and oil platforms. On the other hand, dark formations analysis for oil spill and look-alikes discrimination using auxiliary data suggested that the most frequently observed atmospheric and oceanic phenomena were rain, while algae blooms were also occasionally observed. In addition, based on the digital image processing, texture analysis with combination of correlation, (correlation/entropy) and angular second moment (ASM) as red-green-blue composite image was the most suitable combination for this study. Lastly, oil spills over Makassar Strait in 2018 were estimated up to 45,402.31 Ha.

Keywords: oil spill, look-alike, Sentinel-1, wind, texture analysis