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Enhancing Oil Spill Detection and Response: An Overview of Satellite-based Observation Technologies and Their Impact

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Abstract— **Oil spills are a major environmental issue that requires prompt detection and effective response strategies. Remote sensing technologies have shown great potential in improving oil spill detection and management. This paper aims to review and compare various remote sensing techniques and models used for oil spill detection and response, with a focus on evaluating their effectiveness in preventing offshore oil spills. The study involves a comprehensive review of recent research on remote sensing methods, such as neural network-based detection, Synthetic Aperture Radar (SAR), and optical sensors, alongside oil spill response techniques. The paper also utilizes the *Publish or Perish (PoP)* tool to analyze scientific papers related to oil spill detection and response. The PoP tool was employed to examine citation metrics, methodologies, and trends from 187 studies, including 16 focused on remote sensing techniques, 21 on oil spill methods, and 47 on related concerns. Results indicate that neural network-based methods are effective in high-risk areas, while SAR-based detection is recommended for regions with high sea states or cloud cover. The study also finds that a combination of response techniques, such as containment booms and bioremediation, can significantly improve the effectiveness of oil spill management. Moreover, the integration of multi-sensor data and machine learning techniques shows promise in enhancing detection accuracy and reducing false positives. In conclusion, the paper highlights the need for improved sensor technologies and the integration of various detection and response methods to enhance oil spill management efforts. Future research should focus on refining these techniques and developing cost-effective solutions to enable more efficient and timely responses to oil spills.**

Keywords— Oil Spill detection, Satellite-based Observation Technologies, Synthetic Aperture Radar (SAR), Geographic Information Systems (GIS), Environmental Impact Assessment, Machine Learning in Oil Spill Response.

I. INTRODUCTION

Oil spills threaten the global economy, coastal populations, and marine ecosystems. These accidents have caused long-term environmental harm, including water pollution, a reduction in marine biodiversity, and poor socioeconomic repercussions. Detecting and responding to oil spills is challenging because to a variety of environmental factors, including cloud cover, sea state conditions, and the fast spread of spills across broad distances. Traditional means of identifying oil spills, such as eye inspections and in situ sampling, are frequently ineffective due to time restrictions and a lack of geographical coverage.

Oil spills are classified into four types: small spills, medium spills, big spills, and disaster. These are classified based on the amount of oil discharged into land, coastal, or offshore waterways [1]. Satellite sensors have made oil spills more visible and trackable in recent years. This is achieved using radar in the visible, short, medium, and infrared spectrums, as well as microwave radar. Satellite imagery may substantially benefit in the analysis of oil spills. Satellite images allow us to pinpoint the source of the leak and analyse any possible impact.

A. Biggest oil of the world

Oil spills rank among the most devastating environmental catastrophes, inflicting lasting damage on marine ecosystems and coastal communities worldwide. Several big oil spills have happened throughout the years, each with severe environmental and economic consequences. In 1991, during the Gulf War, Iraqi forces intentionally discharged up to 8 million barrels of oil into the waters of the Persian Gulf, resulting in the most extensive oil discharge ever recorded. Other major oil spills include the Horizon oil rig disaster in the Gulf of Mexico occue in 2010, which released more than 5 million barrels of crude oil, and the 1979 Ixtoc I spill off Mexico's coast, which discharged 3.3 million barrels show in Table 1.

Indonesia has witnessed numerous major oil spills, each with far-reaching environmental and economic consequences. Notably, the Montara oil leak located at Timor Sea in 2010, which originated off the coast of Australia, contaminated marine habitats and disrupted local fisheries in East Nusa Tenggara, Indonesia. In 2018, the Balikpapan oil leak was a significant disaster caused by a Pertamina pipeline that ruptured, discharging about 400,000 barrels of crude oil into Balikpapan Bay. This leak resulted in widespread contamination, the loss of marine life, and a horrific fire that claimed lives. Another important occurrence happened in 2019, when the Karawang oil leak, caused by a blowout at the YYA-1 well near West Java, contaminated coastal waterways and harmed local populations and enterprises. These disasters show

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TABLE 1.
THE WORLD'S LARGEST OIL SPILL [20].

Year	Location	Country	Estimated Oil Spill (million gallons/tons)	Year
1978	Off the coast of Brittany	France	69	1978
1979	Bay of Campeche, Gulf of Mexico	Mexico	140	1979
1979	Off the coast of Trinidad and Tobago	Trinidad and Tobago	88	1979
1983	Off the coast of South Africa, near Cape Town	South Africa	78	1983
1983	Persian Gulf	Iran	80	1983
1988	Atlantic Ocean, off the coast of Nova Scotia	Canada	45	1988
1991	Persian Gulf, near Kuwait and Saudi Arabia	Iran (cause during the Gulf War)	252-336	1991
1991	Off the coast of Angola, Atlantic Ocean	Angola	80	1991
1992	Fergana Valley	Uzbekistan	84	1992
1983	Off the coast of South Africa, near Cape Town	South Africa	78	1983
1983	Persian Gulf	Iran	80	1983
1988	Atlantic Ocean, off the coast of Nova Scotia	Canada	45	1988
1991	Persian Gulf, near Kuwait and Saudi Arabia	Iran (cause during the Gulf War)	252-336	1991
1991	Off the coast of Angola, Atlantic Ocean	Angola	80	1991
1992	Fergana Valley	Uzbekistan	84	1992
2010	Gulf of Mexico, off the coast of Lousiana	United States	210	2010
2011	Off the coast of Tauranga	New Zealand	350-400 tons	2011
2017	Gulf of Paria	Trinidad and Tobago	840000	2017
2019	Red Sea	Egypt	420000	2019
2020	Indian Ocean	Mauritius	1000 tons	2020
2020	Ambarnaya River	Russia	20000	2020
2022	Ventanilla	Peru	500000	2022

continued issues in regulating Indonesia's oil and gas industry, emphasizing the necessity for strict safety and environmental safeguards show in Table 2.

Historical events such as the Horizon oil rig wreck in 2010 and the Persian Gulf leak in 1991 serve as vivid reminders of the devastating effects oil spills may have on the environment and the economy. The tremendous long-term harm that these catastrophes have brought to coastal populations and marine ecosystems emphasizes the critical need for immediate response and preventive actions. When assessing scholarly studies on the issue, a comprehensive awareness of the scope and effects of these breaches gives useful perspective. Researchers may get insight into how well the scientific community is tackling these critical challenges and find areas for improvement by analyzing citation metrics and oil spill investigation techniques.

Oil spill monitoring and detection utilizing remote sensing technologies has emerged as a viable solution to these issues. Optical sensors and satellite-based Synthetic Aperture Radar (SAR) supply vast amounts of real-time data, while machine learning techniques such as neural networks improve categorization accuracy. Despite recent developments, reducing false positives, decreasing reaction time, and separating oil spills from similar-looking maritime phenomena remain major issues.

field. By focusing on papers with the keywords "oil spill," the study aims to gather and review relevant research to understand its contribution and quality.

This study will examine a variety of remote sensing devices and provide effective techniques for managing and preventing oil spills. The findings will lead to improved monitoring systems and reaction frameworks, resulting in more successful oil spill mitigation actions in the future.
Additionally, the study will include a comparative analysis of the methodologies used in these papers. This involves searching for various research approaches and examining their effectiveness to provide insights into the most suitable methods for further investigation. Through this analysis, the study seeks to identify best practices and methodological trends in the study of oil spills.

II. METHODOLOGY

TABLE 2.
CASE OIL SPILL IN INDONESIA

Year	Location	Country	Estimated Oil Spill (million gallons/tons)
2018	Balikpapan Bay, East Kalimantan [21]	Indonesia	16800
2019	Offshore near Karawang, West Java [22]	Indonesia	undisclosed

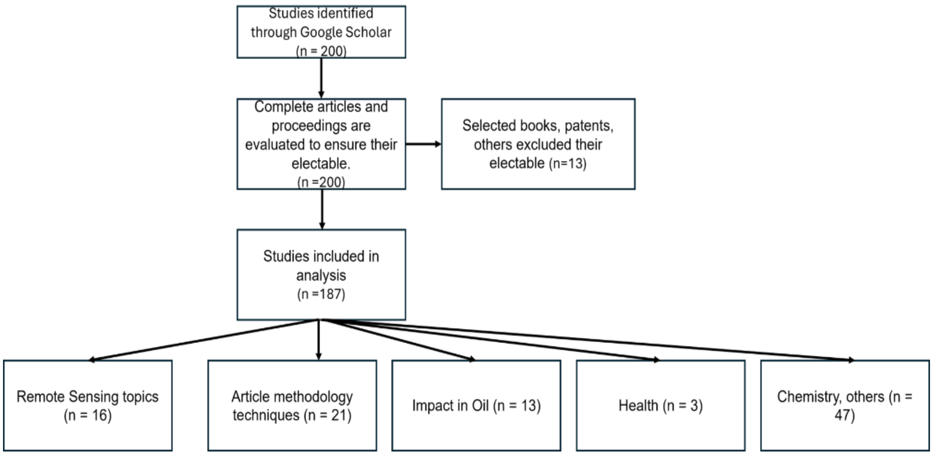

Figure. 1. State-of-the-art POP Data Access

This study is unique in that it thoroughly assesses various remote sensing devices for detecting and responding to oil spills. Unlike earlier research, this study uses the Publish or Perish (PoP) tool to conduct a systematic literature review and analyze research trends, citation metrics, and methodological developments.

This study, which examines 187 papers to identify significant gaps in current approaches, demonstrates the potential of merging multi-sensor data, artificial intelligence, and decision support systems to improve oil spill detection and response.

The primary aim of this research is to evaluate academic papers related to oil spills using the Publish or Perish (PoP) tool. This involves assessing the citation metrics and impact of these papers to determine their relevance and influence in the

A. Data Access

The first step in getting academic papers from Google Scholar via Publish or Perish (PoP) is to install and configure the application by obtaining it from the PoP website. To gain access, choose Google Scholar as a data source in PoP and enter the required API credentials. After launching the app, pick the search option to enter your desired search criteria, such as keywords, publication titles, and author names. To receive Scopus results, execute the query in PoP using your search criteria. Examine the list of publications and utilize PoP's filtering options to reduce your results by journal, citation count, or publication date. Export the data in your preferred format, such as Excel or CSV, to assist further investigation. Examine the citation metrics, such as the h-index and citation counts, to determine the influence of the publications. Furthermore, it can describe your search method by including the filters and criteria you applied and explain the important findings and interpret the results considering your study's objectives. Our POP tool provided the phrase "oil spill," which has the highest ranking of 200, the most citations (2350), and publications from 1970 to 2021 show in Figure 1. We focused on how "oil spill" relates to distant sensing under these conditions. In POP tool, we found that there are journals, proceedings, books, and patents. To assess this, we examined publication schedules, citation metrics, and other research patterns to acquire a better understanding of the link the studies to include in analysis.

B. Active and Passive Remote Sensing

We found that the oil uses the two techniques utilizing the earth observation technology. Oil spill detection technology uses both passive and active techniques to find and track oil contamination on the sea surface.

Active detection oil spill remote sensing

Numerous satellite SAR sensors provide Rapid Response Products, while other active techniques include airborne and spaceborne SAR [2][3]. The discovery of near-surface buried oil was identified by post-spill analysis of lidar data gathered by satellites and airplanes [4]. Post-spill remote sensing data, such as airborne SAR ecosystem oiling maps for tracking damages and hyperspectral vegetation maps, can aid in ecosystem restoration. Although smoke and burning may be detected in real time using lidar and hyperspectral remote sensing, interpretation requires further information. Thermal spectrometry served as an indication of air quality.

Passive detection oil spill remote sensing

Passive remote sensing detects electromagnetic radiation from oil spills, but it is either reflected or emitted. Sentinel-2 [5][6], Landsat-7 [7], Landsat-8 [8], and MODIS[9] are satellites equipped with passive optical sensors. This technology uses infrared and optical sensors to detect the presence of oil by analysing its spectral signature. Passive optical sensors, for example, may detect oil spills because they absorb and reflect sunlight in different ways than water [10]. Oil differs from surrounding water in terms of heat capacity and thermal emission, therefore infrared sensors can detect oil spills. Passive approaches are quite useful for detecting oil, despite being impeded by environmental factors such as cloud cover or weak lighting.

Techniques model for hydrocarbon spill

The oil spill reaction and assessment approach include many strategies for analysing, estimating, and reducing spill consequences. Weathering models replicate oil spill behaviour over time by using mechanisms such as advection, spreading, evaporation, and emulsification to anticipate spill motions and impacts. Matching slick morphologies with wind history and length makes it easier to trace spill sites and trajectories. While feature extraction and classification approaches improve oil spill identification accuracy, modern technologies such as artificial neural networks and neural networks enable quick SAR data detection and classification. The CPD model improves detection capabilities by removing biogenic lookalikes and successfully distinguishing them.

Chemical analysis aimed at contaminating the sea bottom and water column, laser fluor sensors, ultrasonic sensors, and biological, chemical, and physical approaches are all used in oil spill cleaning activities. Identification and monitoring use modern spectrometry, chemometrics, and remote sensing techniques to provide complete environmental protection. The primary aims of this project are to collect data, create models, and evaluate them; semantic segmentation is used to increase model applicability. While categorization and long-term visual data analysis help to comprehend environmental damage and improve leak detection procedures, analytical models and spatial analysis help to estimate spill severity and analyse regulatory implications.

TABLE 3.
ACTIVE AND PASSIVE REMOTE SENSING [10]

Semantic Segmentation Models	Type	Use
Spaceborne Synthetic Aperture Radar (SSAR)[23]	Active Remote Sensing	Detection mechanism, and sensitivity and frequency
Compact Hydrographic Airborne Rapid Total Survey (CHARTS) [24]	Active Remote Sensing	Topograhic Lidar
Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP)	Active Remote Sensing	The water column's upper 40 metres
Thermal infrared (TIR)	Passive Remote Sensing	Upwelling currents, meeting points of water bodies, river discharge, varying water compositions, and past wind patterns.
Airborne Visible Infrared Imaging Spectrometer (AVIRIS)	Passive Remote Sensing	Proportions of oil to water in dense emulsions.

Impact Oil Spill

The study investigates the far-reaching consequences of oil spills on impacted communities by focusing on substantial economic, cultural, and environmental impacts. The disasters have harmed livelihoods, heightened social tensions, and fuelled youth anger since NGOs, the government, and oil companies have done insufficient to help. Many people are unsatisfied and economically stagnant because of the declines in employment, tourism, and traditional farming and fishing businesses. To mitigate these consequences and increase community resilience, the study recommends creating support mechanisms such as monthly allowances for the elderly, infrastructure upgrades, and young engagement in decision-making. Climate change has been shown to make offshore and coastal infrastructure more vulnerable. Temperature fluctuations in the atmosphere and oceans, rainfall trends, the frequency of severe storms, and rising sea levels are all contributing elements to climate change in coastal and offshore locations [11]. This section discusses major climate change elements that may impact the risk of oil and gas leaks and infrastructure on a regional and global scale.

Health Effect

Exposure to oil spills and related chemicals can have several effects on human health, both immediately and over an extended period. Short-term exposure is over a short length of time might range from minutes to days or weeks. When something is stated to have been exposed for a long time, it generally refers to months or even years

III. Results

A. Remote Sensing

Even with recent developments, distinguishing oil spills from comparable surface characteristics remains difficult. The combination of several sensing technologies is critical for improved detection accuracy and reduced false positives shown in Table 3. Improving the ability to monitor oil spills and respond to environmental disasters necessitates continual research into novel methodologies and advancements in present technologies [10].

B. Models for oil spill

TABLE 4.
THE PROCESS AND UTILIZATION MODELS FOR OIL SPILL

Process	Use	Reference
Transport, Expansion, Vaporization, Emulsion Formation, Natural Dispersal, Dissolving, Breakdown, and Settling, Stranding	Weathering models	[25][26]
Wind history and slick length	Matching slick shape	[27]
A neural network provides a categorization algorithm based purely on ERS-SAR data, with no additional information.	Neural Network and Artificial Neural Network can help to locate and assess rapidly	[28][29]
Information manual inspection, automatic detection	Feature extraction and classification	[30][31]
Effective filtering and enhanced discrimination with the CPD model	Biogenic look-alike De-emphasis, and Dual-Polarimetric	[32]
Texture Classifying Neural Network Algorithm and GNOME model	Simulation and Tracking	[33]
Physical, chemical and biological	Clean up oil spill	[34][35]
Ultrasonic, laser fluorosensor, cameras, and chemical analysis	water column and sea bottom	[4]
Initial Fingerprinting, addressing weathering effects, advanced spectrometry, data analysis with chemometrics, Remote Sensing Integration, Underwater Assessment	Identification, monitoring and assessing, detection and surveillance, enhancing environmental protection	[36][37]
Flexible computational grid	Developed model emphasizes its practical application in comparing potential harbor sites	[38]
Data collection, model development, validation, subjectivity consideration	Research tool, model enhancement, and policy and management	[39][40]
Semantic Segmentation, comparison and analysis	Model application for integration into framework and extended use	[41]
Analytical Models (CART, TAN), Geographic	Predicting spill severity, geographic and	[42]

Process	Use	Reference
Analysis, Damage Severity analysis, Vessel Flag and Age Analysis	structural consideration, regulatory and monitoring implication, policy recommendation	
Classification, identification of surface water, imagery-based analysis, extended-period evaluation.	Environmental impact assessment, Leak detection, practical implications	[43]

The models utilized by the PoP tool for oil spill analysis are shown in Table 4. Understanding oil spills and their effects is crucial for formulating efficient response plans. These models help illustrate how spills behave. The transport and development of oil over time may be predicted by using weathering models, which, for instance, replicate natural processes like as emulsification, advection, spreading, evaporation, and dispersion. The course of the spill and its potential affect zones must be evaluated by responders to reduce environmental damage. Using remote sensing data, notably Synthetic Aperture Radar (SAR), sophisticated technologies such as artificial neural networks and neural networks have considerably improved oil spill detection accuracy. Algal blooms and other natural phenomena may be separated from oil spills by feature extraction and classification approaches, as well as dual-polarimetric models such as CPD. When paired with tracking and modelling technologies, these models provide an integrated approach for oil spill management, ensuring successful response operations and continuing environmental monitoring.

TABLE 5.
SHORT-TERM HEALTH EFFECTS

Issues	Symptoms	Cause
Respiratory	Cough, respiratory distress, and chest pain.	Respirating toxic vapors from the oil and dispersants, such as hydrogen sulfide, particulate debris, or volatile organic compounds (VOCs).
Neurological	Headaches, dizziness, nausea, and vomiting.	Small levels of hydrocarbons or hydrogen sulfide in the air might induce acute nervous system injury.
Skin Irritation	Dermatitis, erythema (skin redness), edema (swelling), burning sensations, follicular rash, and secondary skin infections.	Direct contact with oil and chemical dispersants can cause oil loss from the skin, often known as "defatting," which can cause irritation and sickness. Because of their phototoxicity, many hydrocarbons may worsen skin problems when exposed to sunlight.
Eye, Nose, and Throat Irritation	Irritation in the eyes, nose, and throat.	Airborne contaminants, such as gasoline-derived compounds (VOCs), can be harmful.
Heat-Related Illnesse	Heat exhaustion, dehydration, and heatstroke.	Respirators and coveralls are used as safety equipment in hot and unclean environments.

C. Models for oil spill

Environment

Climate change has a significant influence on many forms of infrastructure, particularly in the mining and transportation industries. Rising temperatures endanger permafrost stability and make ice-based transit routes less accessible. Furthermore, they raise the expense and difficulty of maintenance, limit structural load capacity, and speed material deterioration [12]. Droughts induce soil shrinkage, which ruins petroleum and energy transmission pipelines, while intense rainfall and moisture harm equipment, cause mold to grow, and damage storage facilities. Changing precipitation patterns exacerbate the situation [13]. Flooding can affect coastal ports, highways, and bridges[14].

Extreme weather and rising sea levels pose considerable dangers to infrastructure, particularly pipelines, refineries, and oil and gas platforms [15]. While erosion and seawater inundation endanger coastal refineries and gas processing plants, increasing sea levels raise the risk of damage and outage for offshore installations. Severe storms have the power to topple platforms, rupture pipelines, flood seas, and devastate coastal infrastructure[16]. Climate change concerns underscore the importance of enhanced resilience and adaptation strategies in protecting critical infrastructure from the growing hazards connected with it. In addition, the spill's damage had an immediate and long-term impact on a a diverse range of tropical ecosystems, such as coral reef formations, seagrass beds, and mangrove woodlands and estuaries. According to

TABLE 6.
LONG-TERM HEALTH EFFECTS

Issues	Description
Chronic Respiratory	Chronic respiratory illnesses such as asthma and chronic obstructive pulmonary disease (COPD) can result from long-term exposure to particulate matter, volatile organic compounds (VOCs), and other pollutants.
Neurological Damage	Extended exposure to certain hydrocarbons and chemicals can have long-term neurological consequences, such as cognitive decline, memory loss, and other conditions.
Skin Conditions	Extended or recurring exposure can cause hypersensitivity responses, chronic dermatitis, and persistent rashes. Phototoxic responses can cause irreversible harm to the skin.
Increased Cancer Risk	Benzene, a chemical present in crude oil, is among the canned substances. Prolonged exposure may raise the chance of acquiring some malignancies.
Psychological Impact	Working in dangerous settings following an oil spill can lead to post-traumatic stress disorder (PTSD) and anxiety.

[17], the oil spill had a significant impact on the ecology around Karawang Beach in Indonesia.

Operational Impact

The presence of oil spills will disrupt the operational activities of the shipbuilding industry, ship maintenance and shipwrecks because of oil pollution which results in accidents such as fires, damage to facilities and others [18].

Socioeconomics

With substantial drops in seafood prices and sales, particularly in badly afflicted locations, traditional fishing communities, which were already insecure, were struck the hardest. The fact that many clam pickers in the damaged mangrove zones are women has contributed to the spill's increased gender imbalance. Long-term consequences of the oil leak included interruptions to fisherman's financial stability, food supply, and public safety. Those who were exposed to the oil had health problems such as skin infections and diarrhea. In the lack of coordinated federal response, municipalities, non-governmental groups, and other organizations carried out oil cleaning and monitoring initiatives, frequently putting themselves in risk [19].

C. Health Issues

Short- and long-term exposure to contaminants associated with oil spills can have a wide range of adverse consequences on human health.

Short-Term Exposure: Exposure to hazardous compounds during an oil spill, which can range from a few minutes to a few days or weeks, can result in acute health consequences such as headaches, dizziness, nausea, respiratory problems, and skin irritation. These symptoms are frequently immediate and may lessen once the exposure is over, but medical treatment may be required to alleviate them in Table 5.

Months or years of exposure over time might result in more significant and long-term health concerns. Long-term exposure to hazardous compounds can cause chronic skin diseases, cognitive impairment, respiratory issues, and even an increased risk of cancer in Table 6. An individual's health may suffer for years after the exposure, and these long-term effects may not necessarily be obvious straight away.

IV. CONCLUSION

While the study has reviewed various remote sensing techniques and models for oil spill detection and response, it is essential to critically analyze and compare these techniques to determine their effectiveness and suitability for preventing oil spills at sea shown in Table 7. Following a thorough investigation, we recommend the following:

To prevent offshore oil spills, neural network-based detection approaches should be utilized, especially in high-risk areas.

- SAR-based detection methods should be employed in places with high sea states or cloud cover because optical detection techniques may not be effective like technique Sentinel 2 above.
- To increase the precision and effectiveness of oil spill detection and response, different approaches should be used for containment booms, skimmers, chemical dispersants, and bioremediation techniques.

VI. FUTURE RESEARCH DIRECTION

Future research should focus on improving data quality by developing methods to enhance the accuracy and reliability of data used in predictive models and remote sensing techniques. Additionally, efforts should be directed toward creating cost-effective solutions for implementing these techniques, particularly for small-scale operations. Finally, integrating multiple techniques will be crucial for improving the accuracy and effectiveness of oil spill detection and response, ensuring a more comprehensive approach to spill prevention and mitigation.

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REFERENCES

[1] H. Effendi, M. Mursalin, and S. Hariyadi, "Rapid Water Quality Assessment as a Quick Response of Oil Spill Incident in Coastal Area of Karawang, Indonesia," *Front. Environ. Sci.*, vol. 10, no. May, pp. 1–7, 2022, doi: 10.3389/fenvs.2022.757412.

[2] M. I. Habibie, T. A. Pianto, and H. I. Akbar, "Classification of Ship type using Sentinel 1 Imagery," *Proc. - 2021 7th Asia-Pacific Conf. Synth. Aperture Radar, APSAR 2021*, pp. 7–11, 2021, doi: 10.1109/APSAR52370.2021.9688488.

[3] B. Van Ricardo Zalukhu, A. W. Wijayanto, and M. I. Habibie, "Marine Vessels Detection on Very High-Resolution Remote Sensing Optical Satellites using Object-Based Deep Learning," *Proceeding - IEEE Int. Conf. Commun. Networks Satell. COMNETSAT 2022*, pp. 149–154, 2023, doi: 10.1109/COMNETSAT56033.2022.9994340.

[4] M. Fingas and C. Brown, "Review of oil spill remote sensing," *Mar. Pollut. Bull.*, vol. 83, no. 1, pp. 9–23, 2014, doi: 10.1016/j.marpolbul.2014.03.059.

[5] M. I. Habibie and N. Nurda, "Downscaling of vegetation indices from multi-satellite throughout-season maize," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1230, no. 1, 2023, doi: 10.1088/1755-1315/1230/1/012143.

[6] M. I. Habibie and N. Nurda, "Estimation of the Indonesian drought based on phenology vegetation analysis of maize," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1230, no. 1, 2023, doi: 10.1088/1755-1315/1230/1/012144.

[7] M. R. Haryayudhanto, M. I. Habibie, D. A. K. Sari, P. A. Aryaguna, and R. Y. Suryandari, "Green Open Space Assessment Using Vegetation Index Analysis (Case study: North Bekasi District)," *2022 IEEE Asia-Pacific Conf. Geosci. Electron. Remote Sens. Technol. Underst. Interact. Land, Ocean. Atmos. Smart City Disaster Mitig. Reg. Resilience, AGERS 2022 - Proceeding*, pp. 94–98, 2022, doi: 10.1109/AGERS56232.2022.10093665.

[8] R. Shofiyati, M. I. Habibie, M. Ardha, and B. Susanto, "A Multi-Index Satellite Data Investigation for Corn Growth Patterns Identification," *2023 IEEE Asia-Pacific Conf. Geosci. Electron. Remote Sens. Technol. Glob. Challenges Geosci. Electron. Remote Sens. Futur. Dir. City, Land, Ocean Sustain. Dev. AGERS 2023*, no. April, pp. 156–160, 2023, doi: 10.1109/AGERS61027.2023.10490925.

[9] M. I. Habibie, N. Nurda, H. I. Akbar, O. Bibin Bintoro, R. Arifandri, and N. Ramadhana, "Real time monitoring fire detection Using Remote Sensing," *2021 IEEE Asia-Pacific Conf. Geosci. Electron. Remote Sens. Technol. AGERS 2021 - Proceeding*, pp. 28–32, 2021, doi: 10.1109/AGERS53903.2021.9617260.

[10] I. Leifer *et al.*, "State of the art satellite and airborne marine oil spill remote sensing: Application to the BP Deepwater Horizon oil spill," *Remote Sens. Environ.*, vol. 124, pp. 185–209, 2012, doi: 10.1016/j.rse.2012.03.024.

[11] V. Burkett, "Global climate change implications for coastal and offshore oil and gas development," *Energy Policy*, vol. 39, no. 12, pp. 7719–7725, 2011, doi: 10.1016/j.enpol.2011.09.016.

[12] M. Savonis, V. R. Burkett, and J. R. Potter, "Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research," *Systematics*, no. March, p. 445pp, 2008.

[13] M. I. Habibie *et al.*, "Assessing Regional Precipitation Patterns Using Multiple Global Satellite-Based Datasets in the Upper Citarum Watershed, Indonesia," *J. Indian Soc. Remote Sens.*, no. July, 2024, doi: 10.1007/s12524-024-01952-9.

[14] A. Misuri *et al.*, "Technological accidents caused by floods: The case of the Saga prefecture oil spill, Japan 2019," *Int. J. Disaster Risk Reduct.*, vol. 66, no. December 2020, p. 102634, 2021, doi: 10.1016/j.ijdrr.2021.102634.

[15] D. E. Dismukes and S. Narra, "Sea-Level Rise and Coastal Inundation: A Case Study of the Gulf Coast Energy Infrastructure," *Nat. Resour.*, vol. 09, no. 04, pp. 150–174, 2018, doi: 10.4236/nr.2018.94010.

[16] C. M. Patricola and M. F. Wehner, "Anthropogenic influences on major tropical cyclone events," *Nature*, vol. 563, no. 7731, pp. 339–346, 2018, doi: 10.1038/s41586-018-0673-2.

[17] A. Abimanyu, W. S. Pranowo, I. Faizal, N. K. A. Afandi, and N. P. Purba, "Reconstruction of oil spill trajectory in the Java Sea, Indonesia using sar imagery," *Geogr. Environ. Sustain.*, vol. 14, no. 1, pp. 177–184, 2021, doi: 10.24057/2071-9388-2020-21.

[18] M. Watts and A. Zalik, "Consistently unreliable: Oil spill data and transparency discourse," *Extr. Ind. Soc.*, vol. 7, no. 3, pp. 790–795, 2020, doi: 10.1016/j.exis.2020.04.009.

[19] M. O. Soares, C. E. P. Teixeira, L. E. A. Bezerra, E. F. Rabelo, I. B. Castro, and R. M. Cavalcante, "The most extensive oil spill registered in tropical oceans (Brazil): the balance sheet of a disaster," *Environ. Sci. Pollut. Res.*, vol. 29, no. 13, pp. 19869–19877, 2022, doi: 10.1007/s11356-022-18710-4.

[20] S. Tewari and A. Sirvaiya, "Oil spill remediation and its regulation," *Int. J. Eng. Res. Gen. Sci.*, vol. 1(6), no. October, pp. 1–7, 2015.

[21] R. Prastyani and A. Basith, "Utilisation of Sentinel-1 SAR Imagery for Oil Spill Mapping: A Case Study of Balikpapan Bay Oil Spill," *JGISE J. Geospatial Inf. Sci. Eng.*, vol. 1, no. 1, pp. 22–26, 2018, doi: 10.22146/jgise.38533.

[22] Godfried Junio Sebastian Matahelemual, A. B. Harto, and Tri Muji Susantoro, "Oil Spill Detection using Sentinel-1 Multitemporal Data in Offshore Karawang," vol. 2020, pp. 1–21, 2019.

[23] P. M. DiGiacomo, L. Washburn, B. Holt, and B. H. Jones, "Coastal pollution hazards in southern California observed by SAR imagery: Stormwater plumes, wastewater plumes, and natural hydrocarbon seeps," *Mar. Pollut. Bull.*, vol. 49, no. 11–12, pp. 1013–1024, 2004, doi: 10.1016/j.marpolbul.2004.07.016.

[24] P. Carrera, J. H. Churnside, G. Boyra, V. Marques, C. Scalabrin, and A. Uriarte, "Comparison of airborne lidar with echosounders: a case study in the coastal Atlantic waters of southern Europe," *ICES J. Mar. Sci.*, vol. 63, no. 9, pp. 1736–1750, 2006, doi: 10.1016/j.icesjms.2006.07.004.

[25] M. Reed *et al.*, "Oil Spill Modeling an overview of the state of the art," *Spill Sci. Technol. Bull.*, vol. 5, no. 1, pp. 3–16, 1999.

[26] A. K. Mishra and G. S. Kumar, "Weathering of Oil Spill: Modeling and Analysis," *Aquat. Procedia*, vol. 4, no. Icwrcoe, pp. 435–442, 2015, doi: 10.1016/j.aqpro.2015.02.058.

[27] H. A. Espedal and T. Wahl, "Satellite sar oil spill detection using wind history information," *Int. J. Remote Sens.*, vol. 20, no. 1, pp. 49–65, 1999, doi: 10.1080/014311699213596.

[28] F. Del Frate, A. Petrocchi, J. Lichtenegger, and G. Calabresi, "Neural networks for oil spill detection using ERS-SAR data," *IEEE Trans. Geosci. Remote Sens.*, vol. 38, no. 5, pp. 2282–2287, 2000, doi: 10.1109/36.868885.

[29] R. Sunitha, R. S. Kumar, S. Member, A. T. Mathew, and S. Member, "Satellite Oil Spill Detection Using Artificial Neural Networks," vol. 6, no. 6, pp. 1–8, 2013.

[30] C. Brekke and A. H. S. Solberg, "Oil spill detection by satellite remote sensing," *Remote Sens. Environ.*, vol. 95, no. 1, pp. 1–13, 2005, doi: 10.1016/j.rse.2004.11.015.

[31] A. H. S. Solberg, "Remote sensing of ocean oil-spill pollution," *Proc. IEEE*, vol. 100, no. 10, pp. 2931–2945, 2012, doi: 10.1109/JPROC.2012.2196250.

[32] M. Migliaccio, F. Nunziata, and A. Gambardella, "On the co-polarized phase difference for oil spill observation," *Int. J. Remote Sens.*, vol. 30, no. 6, pp. 1587–1602, 2009, doi: 10.1080/01431160802520741.

[33] Y. Cheng, X. Li, Q. Xu, O. Garcia-Pineda, O. B. Andersen, and W. G. Pichel, "SAR observation and model tracking of an oil spill event in coastal waters," *Mar. Pollut. Bull.*, vol. 62, no. 2, pp. 350–363, 2011, doi: 10.1016/j.marpolbul.2010.10.005.

[34] C. Praba Karana, R. S. Rengasamy, and D. Das, "Oil spill

cleanup by structured fibre assembly," *Indian J. Fibre Text. Res.*, vol. 36, no. 2, pp. 190–200, 2011.

[35] G. Alaa El-Din, A. A. Amer, G. Malsh, and M. Hussein, "Study on the use of banana peels for oil spill removal," *Alexandria Eng. J.*, vol. 57, no. 3, pp. 2061–2068, 2018, doi: 10.1016/j.aej.2017.05.020.

[36] J. M. Bayona, C. Domínguez, and J. Albaigés, "Analytical developments for oil spill fingerprinting," *Trends Environ. Anal. Chem.*, vol. 5, pp. 26–34, 2015, doi: 10.1016/j.teac.2015.01.004.

[37] Z. Jiao, G. Jia, and Y. Cai, "A new approach to oil spill detection that combines deep learning with unmanned aerial vehicles," *Comput. Ind. Eng.*, vol. 135, no. December 2017, pp. 1300–1311, 2019, doi: 10.1016/j.cie.2018.11.008.

[38] W. Guo, "Development of a statistical oil spill model for risk assessment," *Environ. Pollut.*, vol. 230, pp. 945–953, 2017, doi: 10.1016/j.envpol.2017.07.051.

[39] J. R. Nelson and T. H. Grubesic, "Oil spill modeling: Risk, spatial vulnerability, and impact assessment," *Prog. Phys. Geogr.*, vol. 42, no. 1, pp. 112–127, 2018, doi: 10.1177/0309133317744737.

[40] Z. Yang *et al.*, "Decision support tools for oil spill response (OSR-DSTs): Approaches, challenges, and future research perspectives," *Mar. Pollut. Bull.*, vol. 167, no. April, p. 112313, 2021, doi: 10.1016/j.marpolbul.2021.112313.

[41] M. Krestenitis, G. Orfanidis, K. Ioannidis, K. Avgerinakis, S. Vrochidis, and I. Kompatsiaris, "Oil spill identification from satellite images using deep neural networks," *Remote Sens.*, vol. 11, no. 15, pp. 1–22, 2019, doi: 10.3390/rs11151762.

[42] E. Cakir, C. Sevgili, and R. Fiskin, "An analysis of severity of oil spill caused by vessel accidents," *Transp. Res. Part D Transp. Environ.*, vol. 90, no. December 2020, p. 102662, 2021, doi: 10.1016/j.trd.2020.102662.

[43] P. Tysiąc, T. Strelets, and W. Tuszyńska, "The Application of Satellite Image Analysis in Oil Spill Detection," *Appl. Sci.*, vol. 12, no. 8, 2022, doi: 10.3390/app12084016.