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Comparing the Suitability of Sentinel 1 and 2 Imageries to Study the Wakashio Oil Spill at an Island in the Indian Ocean

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ABSTRACT

Mauritius is a biodiversity hotspot with a high concentration of plants and animals unique to the region. The Mauritian marine environment is home to 1,700 species including around 800 types of fish, 17 kinds of marine mammals and two species of turtles. Coral reefs, seagrasses and mangroves make Mauritian waters extraordinarily rich in biodiversity. An oil spill can be characterized as the coincidental arrival of fluid petrol hydrocarbon into the environmental factors or the climate because of human action. An oil spill is a type of contamination that has a devastating effect on the climate. The Undertaken study emphasizes on the recent oil spills on the Mauritius Southeast Coast on 25th July 2020. The Japanese claimed mass transporter MV Wakashio vessel, which conveyed almost 4000 tons of oil, ran on solid land on a coral reef on Mauritius' southeast coast on 25th July 2020. More than 1000 metric huge loads of fuel have been spilled into the Indian sea contaminating the close by coral reefs, the encompassing sea shores and lagoons. This study investigates the Wakashio oil spill by using Sentinel-1 SAR data and Sentinel-2 optical to determine the spill's progress, compare both the image suitability to the study and analyse its effects on the coastal ecosystem. The processing of VV polarization images from Sentinel-1's Synthetic-Aperture Radar (SAR) C-band obtained on 10 August 2020 revealed the presence and spread of oil spills as dark warped patches. The images of Sentinel-2 data were utilized to detect the oil spill using the threshold anomaly value approach. Sentinel-1 SAR data processing was performed using the Sentinel Application Platform (SNAP) of European Space Agency (ESA) and Sentinel-2 Optical data processing was performed using QGIS. Field visits were used to validate the satellite-derived results. The Sentinel-2 data confirmed the Sentinel-1 SAR results by demonstrating the existence and spread of oil spills of varying thicknesses. This study revealed the capabilities of Sentinel sensors and the possibility of image processing methods for detecting, monitoring, and assessing the environmental effect of oil spills.

***KEYWORDS**: sentinel 1, sentinel 2, Wakashio oil spill, Mauritius, SNAP, QGIS*

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I. INTRODUCTION

An oil spill can be characterized as the coincidental arrival of fluid petrol hydrocarbon into the environmental factors or the climate because of human action. An oil spill is a type of contamination that has a devastating effect on the climate. The term oil spill is at times used to allude to marine oil spills where there is an arrival of oil into the sea, seaside waters or some other water body. On the land the oil spills are generally limited and their effect can be wiped out effortlessly contrasted with marine oil slicks. The fundamental driver of marine oil spills is related with the oil transportation by big haulers and oil pipes which makes up of around 70% of all the oil slicks. The leftover percent of oil spills comes from seaward penetrating, wells and spills of refined oil-based commodities like petroleum and diesel and furthermore their side-effects. The event of enormous and catastrophic spills that can deliver as much as 30,000 tons of oil or significantly more is generally uncommon. The recurrence of such occasions lately had gone down discernibly. Yet, this went in a new direction when we encountered the more regrettable and biggest oil slick at any point recorded ever, deep water horizon oil spill also known as the Gulf of Mexico oil spill. In spite of the fact that some oil spills may not be as broad, however they actually have the capacity to make genuine biological dangers to ocean birds and other mammals. The outcome is the drawn-out natural aggravations that happen in waterfront zones. Oil slicks likewise affect the monetary exercises of individuals that rely upon the ocean for an occupation. Public objection over oil slicks has prompted the coming up of noteworthy technical, political and furthermore lawful encounters in overseeing oil spills.

The Undertaken study emphasizes on the recent oil spills on the Mauritius Southeast Coast on 25th July 2020. The Japanese claimed mass transporter MV Wakashio vessel, which conveyed almost 4000 tons of oil, ran on solid land on a coral reef on Mauritius' southeast coast on 25th July 2020. More than 1000 metric huge loads of fuel have been spilled into the Indian sea contaminating the close by coral reefs, the encompassing sea shores and lagoons. The district is a Global biodiversity Hotspot. The island of Mauritius pronounced a 'condition of ecological crisis' after the spilling of oil into the sea began.

A methodology coordinated towards an improvement in oil spill discovery/recognizable proof in the ocean with the utilization of satellite pictures as the essential wellspring of data has been created. Remote Sensing has demonstrated fit for evaluating oil pollution. The satellite concise view is an alluring choice to recognize the oil spill type that can prompt significant logical advances. Response personnel can utilize this current area's Sentinel 1 (SAR) and Sentinel 2 (MSI) Imagery Capability for Oil Spill Detection in Mauritius Southeast coast. With the information on spill areas and movements, response personnel can successfully plan countermeasures to diminish the impacts of the contamination. Remote Sensing can identify the oil slick region in view of the spectral and backscatter characteristics for its spill in the water. Despite the fact that it has been viewed as that the satellite-borne SAR sensors have been extensively utilized for oil slick checking, have given superb information, and assumes an imperative part in oil spill recognition for its the entire day-and-night detecting capacity, the use of optical imagery actually be utilized to comprehend the ability of the two imagery in recognizing the oil slick. Satellite imageries, both active (radar) and passive (optical) sensors are every now and again used to identify, guide, and screen the oil spills. Consequently, in this investigation, Sentinel 1 (Synthetic-Aperture Radar/SAR) and Sentinel 2 (Multispectral Sensor Imager/MSI) are utilized for oil spill discovery in the Mauritius Southeast coast in light of its temporal and spatial availability covering this region. The target of this exploration was to look at the ability of the two imageries for distinguishing the oil spill in the sea. To be exact, this exploration is endeavouring to analyse the ability of Sentinel 1 (SAR) and Sentinel 2 (MSI) for mapping the oil spills along the South-eastern coast of Mauritius.

II. STUDY AREA

The study area covers the South Eastern Coast of Mauritius Island located in the Indian Ocean (latitude: 20°10′ S and longitude:57°30′ E), which had a serious occurrence of oil spill on July 25, 2020.The Japanese owned bulk carrier MV Wakashio vessel ran aground on a coral reef on Mauritius's southeast coast on 25th July 2020. More than 1000 metric tons of fuel have been leaked into the Indian ocean polluting the nearby coral reefs, the surrounding beaches and lagoons. When a crack formed on its hull after 12 days, the spill happened, and the spill continued for several weeks. The ship broke up on August 16, 2020, and the forwarding portion of the ship was scuttled on August 20, 2020.

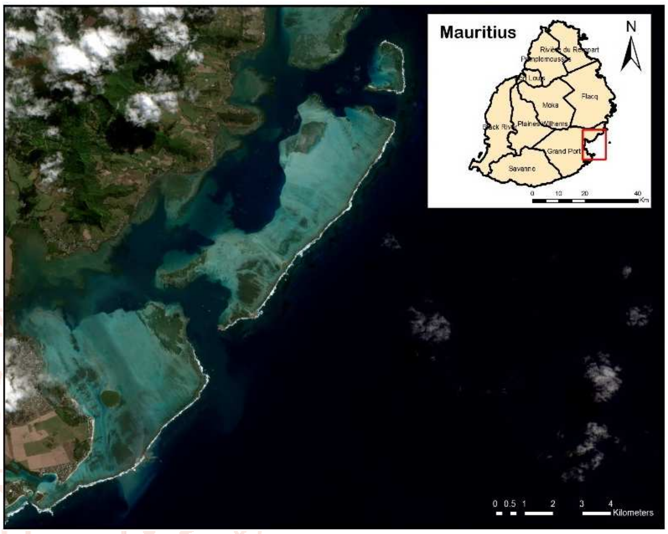

Fig.1 Study Area Map

III. Datasets Used

In this study, Sentinel-1 and Sentinel-2 satellite imagery was used to detect and map the Mauritius oil spill.

Both satellite imageries were downloaded from the Copernicus ESA website (https://scihub.copernicus.eu/dhus/).The following tables summarizes the details of datasets.

Table 1: Sentinel 1 Data

SI. No	Satellite	Product name	Date and time	Product Type	Acquisition mode	Polarization	Spatial Resolution
1	Sentinel-1	S1B_IW_GRDH_1SDV_20200810T013755_20200810T013820022854_02B625_672D	2020-08 10 T01:37:55.041Z	Level 1 GRD product	Interferometric Wide Swath (IW)	VV VH	10x10 meters

Table 2: Sentinel 2 Data

SI. No	Satellite	Product name	Date and time	Product Type	Instrument	Spatial Resolution
1	Sentinel-2	S2A_MSIL1C_20200811T062451_N0209 R091_T40KEC_20200811T094614	2020-0811T 06:24:51.024Z	S2MSI1C	MSI	10x10 meters

IV. DATA PROCESSING

The study was carried on using both Sentinel 1 and Sentinel 2 in order to find their capabilities in mapping out the Wakashio Oil Spill. The under mentioned procedure was adopted to find and compare their individual capabilities.

Sentinel 1B Image was downloaded from the Copernicus ESA website. The data was downloaded for 10th of August 2020 with a spatial resolution of about 10 metres. In order to process the SAR (Synthetic Aperture Radar) Data, SNAP Sentinel toolbox version 8.0 was roped into the study. The required area of interest i.e., Offshore of Pointe d'Esny, the South Eastern Coast of Mauritius was clipped out after performing the subset process in SNAP toolbox. Once done with the precise area of interest, SAR pre-processing was done which is aimed at correcting the data both radio metrically and geometrically. The pre-processing of SAR data includes:

Thermal Noise Removal: In many detected SAR satellite images, the presence of additive noise can be noticed, especially in areas of low backscatter (like calm sea, lakes, etc.). Unlike quantization noise, which is dependent upon the signal power itself, the thermal noise can hardly be noticed, and becomes relevant only where the signal mean is low. Furthermore, in multi-swath acquisition modes this noise has typically a different intensity in each sub-swath, causing an intensity step at inter-swath boundaries. During raw data focusing, data (including the noise contributions) are multiplied by several fast time-varying radiometric correction factors. The result is that noise contributions are re-shaped in a range-varying fashion. Thermal noise removal reduces noise effects in the inter-sub-swath texture, in particular, normalizing the backscatter signal within the entire Sentinel-1 scene and resulting in reduced discontinuities between sub-swaths for scenes in multi-swath acquisition modes.

Calibration: SAR calibration is aimed to convert DN in form of amplitude to sigma naught or Normalised Radar Cross Section (NRCS). The calibration was performed on Sentinel Application Platform (SNAP) based on the lookup tables provided within the product.

Speckle Filtering: GRD product is essentially multi-looked product with reduced speckle noise. However, it is undeniable that speckle noise is not completely removed. Therefore, speckle filtering was done to smoothen the image and reduce the speckle. Lee speckle filtering was reported to be effective reducing high speckle noise without sacrificing oil spill's edge.

Terrain Correction: Radiometric terrain correction addresses two aspects of adjusting the effects of side--looking geometry of SAR imagery. First, the geometric distortions are corrected by using a digital elevation model. Second, the brightness, or radiometry, is adjusted in the affected foreshortening and layover regions.

After all these, the result was converted to db values so as to improve the image contrast specially to differentiate between the spill and other objects. Visual separation of the oil spill can be understood through the dB value. Generally, the oil spill object has a low dB value from the surrounding object because the backscatter reflection value is low. Oil films can be detected as dark patches relative to the surrounding water as they dampen the wind-generated short surface waves. Finally oil spill mapping is done using SNAP

After that, Sentinel 2 imagery was processed using QGIS tools. To convert the digital number (DN) value to reflectance value, the semi-automatic classification has been used. Similarly, the oil spill index (Equation 1) can be used to analyse images in order to identify oil spill zones. The standard deviation of Band 2 in Sentinel 2 is used in the formula, as well as the result of the band ratio of Band 2 with Band 11. The visual interpretation of images with the help of Google Earth Pro was found to be one of the most important approach for studying the distribution of oil spills and related features in this research. Figure represents the entire process of obtaining oil spill data using Sentinel 1 (SAR) and Sentinel 2 (MSI) imagery. The findings of all image processing will be compared in order to determine each image's capabilities in mapping the Mauritius oil spill.

$$Oil\ Spill\ Index = StDev\ B2 * B2/B11 \ldots\ldots\ (1)$$

V. METHODOLOGY

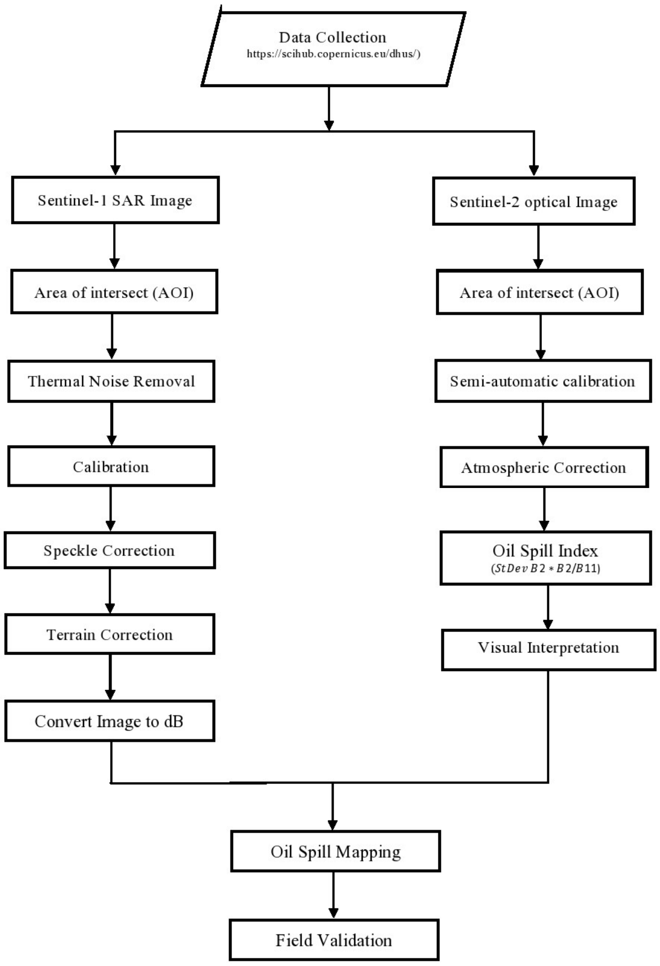

Fig 2 Schematic Flowchart of pre-processing and image analysis of Sentinel 1 and 2 data

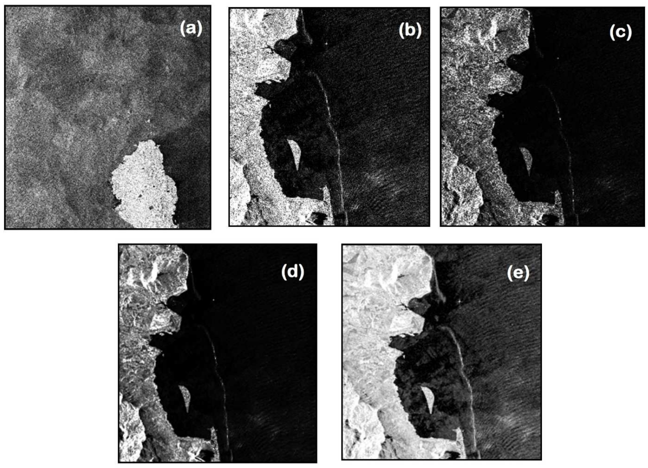

Fig 3 Sentinel 1 Image Processing Results. (a) Raw Image (b) Subset Image (c) Calibration (d) Speckle Correction Results (e) Linear Transformation of dB Value Results

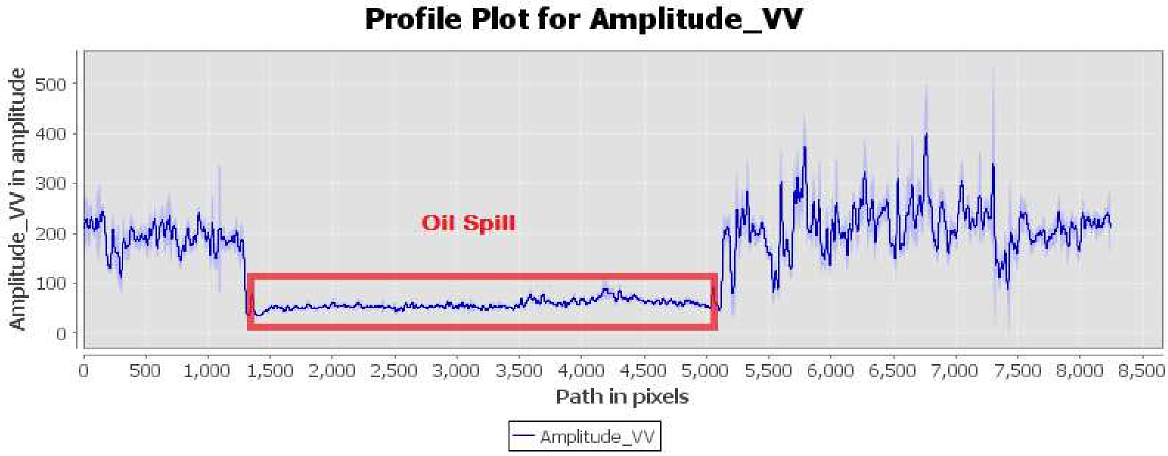

Fig 4 Histogram of dB Value for the Oil Spill and Non-Oil Spill Object

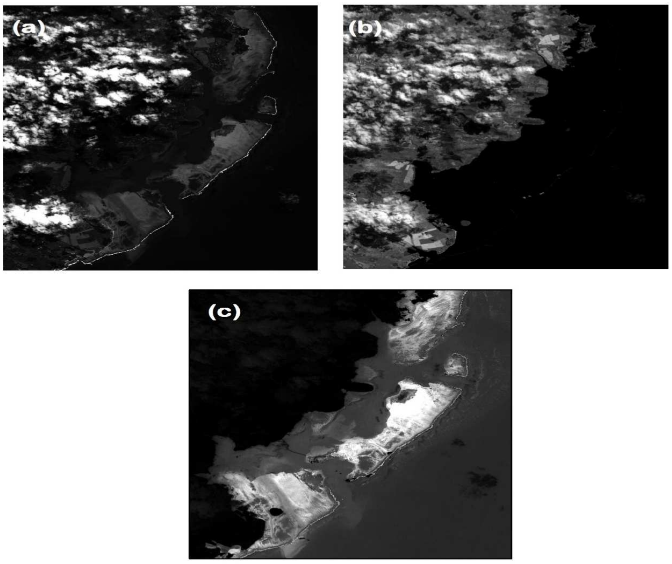

Fig 5. Results of Sentinel 2 Image Processing. (a) Band 2 Images Which Has Been Applied by Atmospheric Correction (b) Band 11 Images Which Has Been Applied by Atmospheric Correction (c) Oil Spill Index Results

VI. RESULTS AND DISCUSSION

The Results by processing Sentinel 1 is very much appreciable in identifying the oil spill (Fig 6). The histogram values show clearly that lower values are for the oil spills than that of its surrounding objects. The oil spill is clearly visible due to the increased contrast after transforming the values to db. The interpretation of oil spills over images obtained on August 10, 2020 clearly demonstrates the existence of oil spills as dark warped areas with a spreading width. Though the images indicate the thickness of the spilled oil or the kinds of oil, the changes in thickness may be understood and evaluated based on the shades of darkness, especially indicate the thickness of the spilled oil or the kinds of oil, the changes in thickness may be understood and evaluated based on the shades of darkness, especially when the oil spill was sufficient at the location (as shown by the backscatter values of oil in the horizontal profile).The identification of oil spills and surface waves is made possible by SAR's VV polarization, which gives greater radar backscatter and the high dielectric constant of the sea surface. But however in this study the classification of thin and thick oil spills is performed using Sentinel 2 image interpretation.

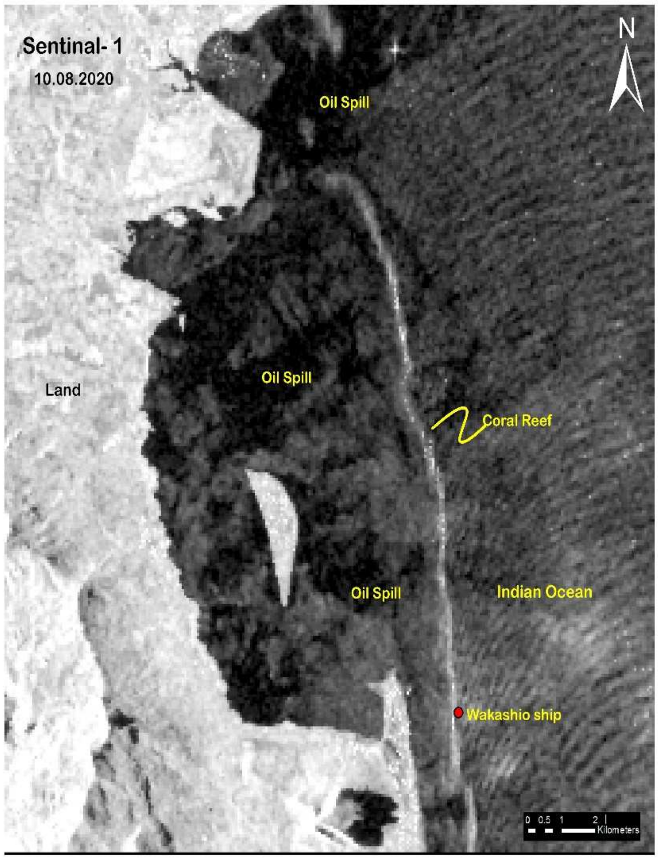

Fig 6 Area of the Oil Spill Based on Sentinel 1 Image Processing

The spectral signature captured by the Sentinel image sensor can be used to identify the presence of an oil spill in Sentinel 2 (MSI) imagery. The oil spill area can clearly be seen based on the oil spill index processing. The images of the oil spill index show the land area in red colour and coarse texture, the offshore water in orange with fine texture. The image often shows the appearance of a ship and an oil leak in the area of the incident and over the coral reefs in Blue colour with fine texture. Light blue (thick oil spill) to yellow (thin oil spill) of fine texture, the oil spills in and around the ship are distinguishable from light tone (Fig 7). The spread of leaked oil over other regions is shown in shades of red, and the spread can be easily interpreted using Google Earth Pro.

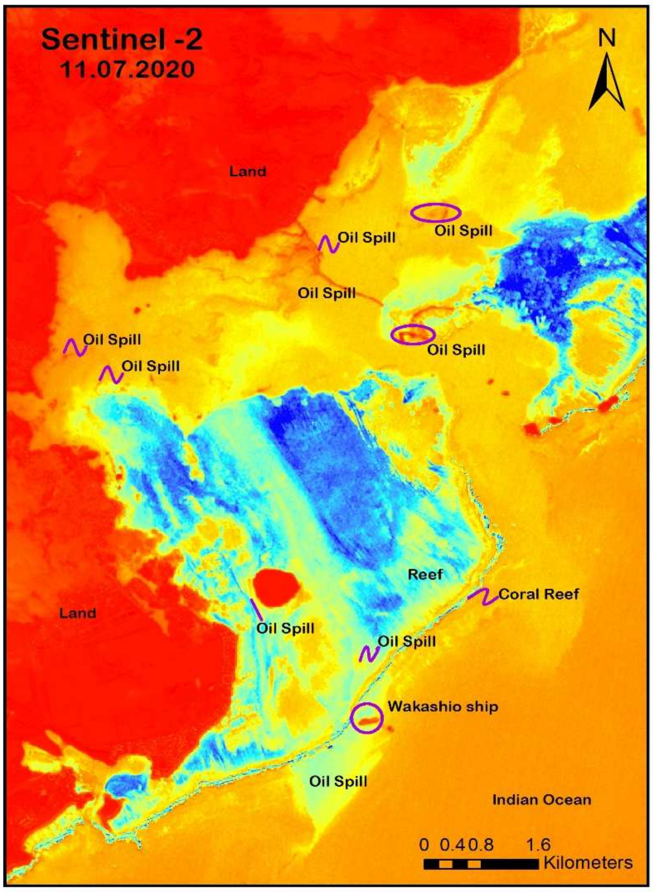

Figure 7 Oil Spill Area Based on Sentinel 2 Image Processing

VII. VALIDATION OF OIL SPILL MAPPING

Aerial images taken during the incident show that Wakashio ran aground on a coral reef, and oil started to spill from the ship after cracks formed in its hull(fig 8 a & b). On August 8, 2020, a (fig 8c) shows a fire crew operating at the location of an oil leak after the bulk carrier ship MV Wakashio went aground on a reef in Riviere des Creoles, Mauritius. This aerial view, taken on August 8, 2020, shows leaking oil from the vessel MV Wakashio being driven by currents into the Grand Port Bay, near the Bois des Amourettes(fig 8i). The field photos capture the volunteers collecting leaked oil in order to protect the buildup of oil along the coast on the August 10, 2020(fig 8e). On August 9, 2020, people scoop leaking oil outside Blue Bay Marine Park in southeast Mauritius (fig 8c). On August 7, 2020, the vessel MV Wakashio was photographed after it ran aground near Blue Bay Marine Park off the coast of southeast Mauritius (fig 8d). This aerial photograph was taken on August 6, 2020, and depicts a huge patch of leaking oil from the vessel MV Wakashio off the coast of southeast Mauritius (fig 8f). On August 9, 2020, oil was leaked from the MV Wakashio off the southeast coast of Mauritius, according to a photo released by the French Defense Ministry (fig 8g). The leaked oil was pushed into the lagoon by waves that crossed the coral reef ridge. Aerial images can be used to study the interpretation of oil spills that scatter over both sides of Ile aux Aigrettes, across the lagoon and coral reefs, and along the coast using Sentinel data (fig 8h). The field photographs also help us to determine the consequences of oil deposition along the coast.

Fig. 8(a-i). Aerial and field photographs

VIII. CONCLUSION

Sentinel 2 images capability in detecting oil spill objects in South-eastern coast of Mauritius is generally not good compared to the results of identification of Sentinel 1 images. It can happen due to the presence of cloud objects and sediments around the coastal area which was detected as oil spill objects. The utilization of Sentinel 1 (SAR) and other active imageries give better capabilities in oil spill detection. Sentinel-1 and Sentinel-2 data collected during the incident validated the oil spill event and the occurrence, spread, and deposit of the spill. The aerial and field images collected during the incident were used to validate all of the results. This study proved the use of Sentinel-1 and Sentinel-2 sensors, as well as the capability of image processing techniques, to monitor and analyse the oil spill.

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