D-4.3 Study on Monitoring Method of Coastal Ecosystem due to the Gulf War with Satellite Remote Sensing

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Abstract Remote sensing with satellite imageries were applied to the environmental monitoring around Percian Gulf to evaluate the damage caused by the Gulf War. Smoke palls from burning oil fields were detected by NOAA/AVHRR imageries and the extent of the damaged areas was evaluated. Also, the floating oil spills released from the destroyed oil tanks were detected by LANDSAT TM imageries. Vegetation, soil and water conditions affected by the released oil spill and the smoke palls were evaluated by using satellite imageries and by spectral signature data measured on the ground.

Key words : Percian Gulf War, remote sensing, oil spill, smoke pall

1. Introduction

The Persian Gulf War gave fatal effects to gulf environment including ocean and desert ecosystems because of oil spills or smoke palls from burning oil fields. The damaged area was too wide to evaluate its effect in quality and quantity using conventional ground survey methods. The objective of this study is to assess environmental impact to the Gulf ecosystem due to the War with remotely sensed satellite imageries.

First, satellite imageries from NOAA AVHRR were collected and the extent of the area suffered from the smoke palls was evaluated. Also the field survey to collect basic ground truth data for the analysis of remotely sensed data was carried out at Dahran and Jubail areas in Saudi Arabia after the war. The collected spectral signature data showed the significant differences between the damaged coastal sand and the normal sand, and indicated the possibility of assessing the damage due to theWar from remotely sensed imageries.

Next, oil spill detection method was developed and oil spill maps were produced from LANDSAT TM imageries. The nomalized

difference index using band 5 & 4 of TM data was proved to be effective for the detection of oil spill over the ocean surface.

2. Oil spills and smoke palls in the Gulf War

The Gulf crisis started with the Iraq invasion of Kuwait on August 2, 1990 and came to an end by the surrender of Iraq on February 28, 1991. Iraqis troops set fire to over 600 oil wells in several Kuwait oil fields. Perhaps as much as 11 million barrels of oil were released to the Gulf. More than 800 km of Kuwaiti and Saudi Arabian beaches were heavily oiled[1]. Also smoke palls from burning oil wells covered ocean and desert areas around the Gulf and a huge amount of atmospheric pollutants dropped over the area.

The oil was mainly released from Mina Al-Ahmadi of South Kuwait. The major oil spill started on January 20, 1991 and stopped by the alliance army on January 28, 1991. The spilled oil was driven by the north west wind. Many of oil slick were traced to the Kuwait and Saudi Arabian beaches and reached at the south of Abu Ali Island in Saudi Arabian territory on February 14, 1991, which was sellected as one of the study areas of the research.

The smoke palls reached to Saudi Arabia and Katar and gave significant damage to ecosystems including vegetation and soil environment.

3. Evaluation of the extent of smoke palls

The extent of the areas affected by smoke palls from the burning oil fields was evaluated by NOAA AVHRR imageries. NOAA AVHRR is an earth observation sensor with 5 bands covering visible and near-infrared wavelength range and it can observe 2700km swath with 1km spatial resolution. Total of twenty nine NOAA AVHRR imageries during the WAR were collected and the areas covered by smoke palls were extracted. Figure 1 shows the NOAA AVHRR imagery February 12, 1991 after the enhancement of the smoke pall. The area extended to the boarder between Saudi Arabia and Katar and covered the most areas of Saudi Arabia's east coast.

4. Spectral signature characteristics of vegetation and soil

In order to investigate the possibility of remote sensing of the damage by oil spills and smoke palls to vegetation, soil and water, their spectral reflectance was measured at the coastal areas around Jubail and Duhran using the portable spectrometer and the spectral signature characteristics were evaluated. Figure 2 shows the examples of the spectral reflectance of sand (polluted sand, normal sand,oil spill) and vegetation (green, yellow and dry grass). The measured spectral reflectance shows the clear difference between the polluted sand and normal sand and indicates the possibility of the classification between them from the remotely sensed data.

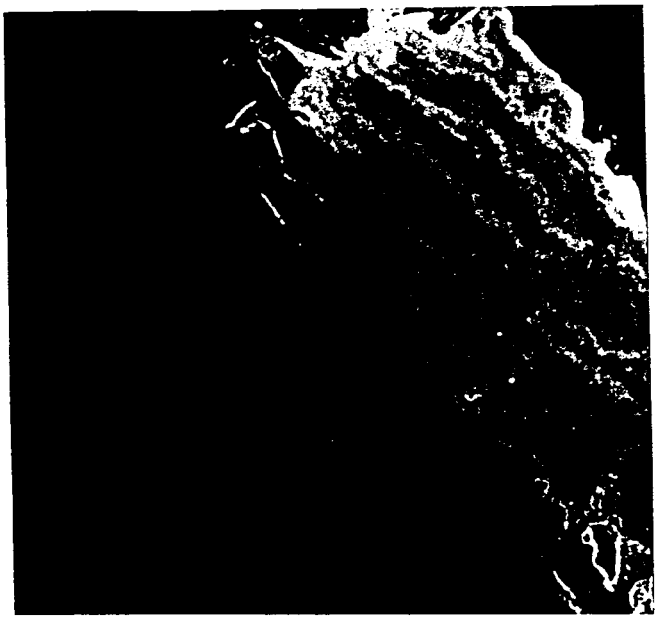
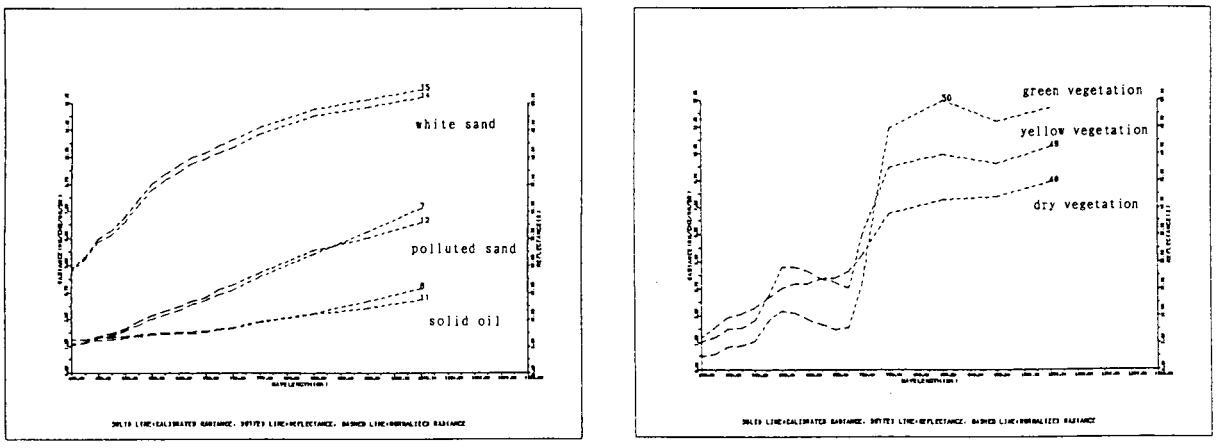


Fig.1 NOAA/AVHRR image showing smoke palls from the burning oil fields (after image enhancement)



(a) (b)

Fig.2 Spectral Signatures of sand and vegetation.

5. Detection of oil spill using LANDSAT TM data

There have been two kinds of methods for the detection of oil spills. One uses the thermal infrared range and the other uses the middle infrared range.

Salisbury *et al.*(2) showed the spectral characteristics at the thermal infrared by direct measurement of the reflection of oil slick using a spectrometer. Also, Legg(3) and Cross(4) detected the oil spill of the Gulf War using the thermal band of NOAA/AVHRR. On the other hand, Stringer(5) succeeded in the detection of the crude oil by the Exxon Valdez using the middle infrared band of LANDSAT TM sensor.

In this study, middle infrared was used to detect oil spills. Two LANDSAT TM imageries were used to detect oil spills around Jubail and Abu Ali Bay, Saudi Arabia February 16, 1991 and March 20, 1991. The images cover about 180km*180km with 30m spatial resolution. For the detail analysis, the area of approx. 30 km x 30 km was cut out from the original image.

The 63 training areas were extracted from two images and the average brightness value of band 1-7 was calculated. Several indices were investigated to emphasize the spectral feature of oil spill and, as a result, the normalized difference index using band 5 & 4 was proved to be the most effective for the discrimination of oil spill.

The normalized difference index of band 5 & 4 was classified into three levels as follows. On the other hand, the brightness value of the TM band 4(near infrared band) was used to make a mask of land area.

NDOI = (TM5-TM4)/(TM5+TM4)
COI = (NDOI+1.0)*127
COI 0 - 140 Sea surface without oil
141 - 177 Sea surface with little oil
178 - 255 Sea surface with oil

Here, NDOI and COI are abbreviation of Normalized Difference oil Index and Caribrated Oil Index, respectively. Figure 3 shows the oil spill distribution detected by the NDOI and COI.

In the image of February 16, the oil spill is flowing from the northwest into the Abu Ali Bay area taking shape of slender belt and reaching at the west of the Abu Ali Island. In the image of March, there is no area showing high COI value above 178, but slight oil spill is still remaining inside the Bay. The result shows that the remote sensing from satellites is highly effective to detect the oil spills floating over water surface.

4. Discussions

Remote sensing with satellite imageries was applied to the detection of oil spills and smoke palls from destroyed oil tanks by the

Gulf War, and their distribution were estimated. NOAA/AVHRR images were effective to detect smoke palls because it can cover more than 2500km^2 with 1km spatial resolution, whereas LANDSAT TM imageries were effective to detect oil spills in more localized areas.

The results indicate the effectiveness of remote sensing methods for the monitoring of large scale environmental damages caused by accidents or wars. It would be necessary to continue to monitor environmental changes after the War to evaluate its long term effects.

5. Reference

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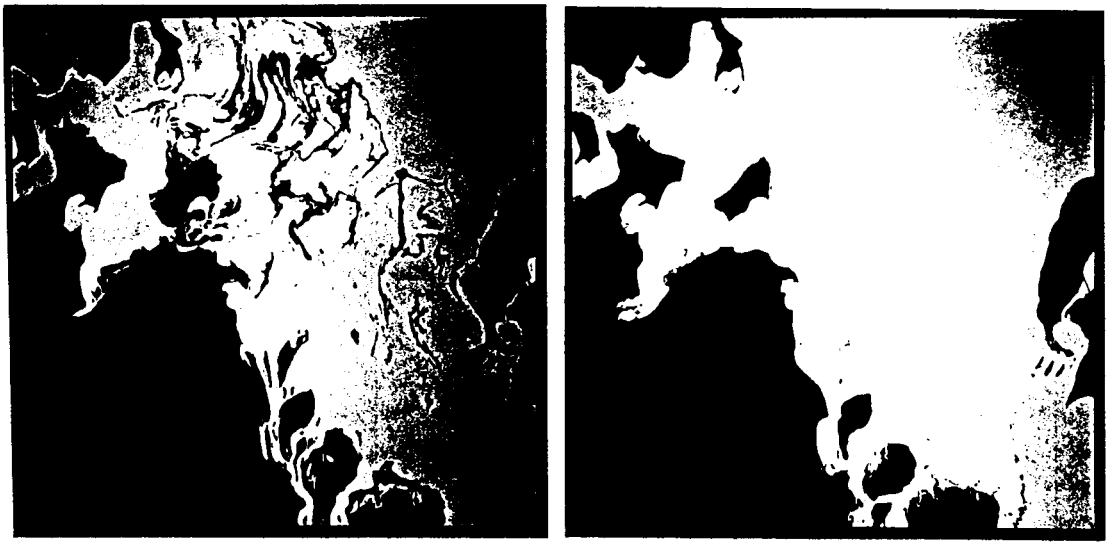

(a) February 16, 1991 (b) March 20, 1991

Fig.3 Oil spill distribution detected by LANDSAT TM imageries.