Spectral Analysis of 1991 Persian Gulf Oil Spills Using LANDSAT Imagery

Lab 2 Report by Skyler Elmstrom

Methods

Data used in this analysis were provided by Professor David Wallin, Western Washington University, and adapted from Professor Paul R. Baumann, State University of New York College at Oneonta.

Our analysis began by isolating oil spills in selected LANDSAT imagery over Ad Daffi Bay. LANDSAT bands in the visible spectrum (bands 1-3) do not provide enough spectral information to differentiate oil from water and oil from land, so bands 4 (near-infrared or NIR) and 5 (Shortwave-infrared or SWIR) were used to identify oil slicks on the surface of water due to oil's characteristically high reflectance in the SWIR spectrum and near 0% reflectance of water in the NIR spectrum (Baumann 2001). Manual visual inspections of TM band 5 and its associated histogram were conducted to "guess" a best fit range of pixel values representing "light" and "heavy" oil, land, and water in our image following the recommended guidance provided by Professor D. Wallin (Wallin 2017). The pixel value ranges were narrowed down further using band 4 to create a land and water mask to be applied to band 5. This reduced the likelihood that values with similar reflectance to oil on land and on water were included in our oil analysis. A pseudo color scheme was applied based on our identified frequency ranges for land, water, light oil, and heavy oil for ease of visualization and our masked band 5 histogram values were exported to calculate the approximate area of oil spills in Ad Daffi Bay.

Results

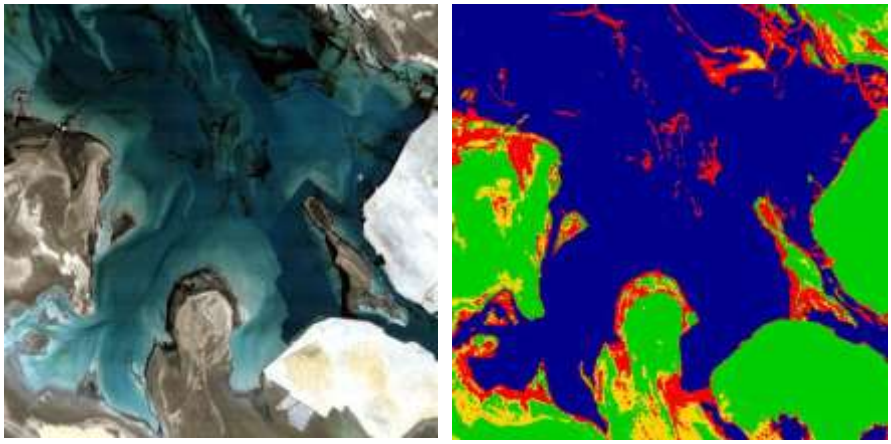

Figure 1. True color image of Ad Daffi Bay (left) and pseudo-colored TM band 5 showing initial spectral groupings (right) based on manual classification of land, water, and light and heavy oil slicks. In the pseudo-color image (right) blue represents water, green is land, red is light oil, and yellow is heavy oil.

Our initial isolation of oil by visual observation using band 5 narrowed down the frequencies being analyzed but some errors and noise can be immediately observed. In figure 1 above, large portions of land appear to be classified as light and heavy oil and some areas of land were classified as water. Misidentified areas were determined by comparing our true-color image of Ad Daffi Bay to our pseudo-color analysis; the misclassifications caused by our initial frequency ranges stand out. The histogram data of TM band 5 also reinforces that there were significant misclassifications in the value ranges we assigned; initial estimates suggest that 16% of our

	Min. Value	Max. Value	Area (pixels)	Area (hectares)	Area (percent)
Land	60	255	73042	6573.78	27.8631
Water	5	16	145644	13107.96	55.5587
Light Oil	17	52	26199	2357.91	9.9942
Heavy Oil	53	59	17238	1551.42	6.5757

Figure 2. Feature types, pixel value ranges, and area calcualtions of TM band 5.

image was classified as light or heavy oil (Fig. 2). This includes faulty classification of some land features with similar reflectance as oil pixels. To correct for the misclassification of land as oil,

TM band 4 was used to precisely delineate water from land by recalculating pixel values in a binary format: land=0 and water=1. This modified TM band 4 was then multiplied to TM band 5

Figure 3. Black and White, unmodified image of TM Band 5 (left), TM band 4 land/water mask (mid), and the resulting multiplication of TM band 5 to the TM band 4 land/water mask (right). Oil slicks with high spectral reflectance stand out among the low-reflectance water features and the masked-out land features.

to mask out all land pixels. The result of this process shows an improvement over the initial classifications when land values were removed from the analysis (Fig. 3). Our masked TM 5 image accentuates high-reflectance features in water, previously identified as a characteristic of oil, while subduing all land values that were previously misclassified. Comparison between the two TM band 5 images, before and after the mask was applied, shows masking land values improved the quality of our analysis (Fig. 4). Once our analysis was improved, an accurate estimate of the total area affected by oil could be ascertained; the histogram provides an exact pixel count per value and each pixel represents a 30m x 30m space. Our updated analysis

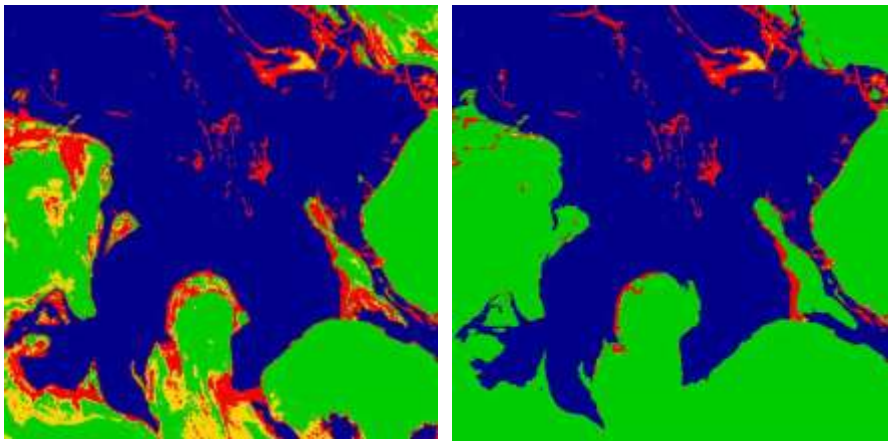

Figure 4. Pseudo-colored TM band 5 before land/water mask (left) and pseudo-colored TM band 5 after land/water mask.

showed that oil contributed about 4.4% of the total area in our image (Fig. 5). This number appears to be more reasonable than our initial estimate as it is more consistent with visual

	Min. Value	Max. Value	Area (pixels)	Area (hectares)	Area (percent)
Land	0	0	111548	10039.32	42.5522
Water	1	16	139088	12517.92	53.0579
Light Oil	17	52	10552	949.68	4.0249
Heavy Oil	53	59	922	82.98	0.3517

Figure 5. Feature types, pixel value ranges, and area calculations of TM band 5 after land/water mask.

observations of the original image. Our final estimations suggest that out of the total image area of approximately 24,000 hectares, roughly 1,000 hectares were affected by oil spills.

Discussion

While the improvements on the initial analysis were beneficial, more could be done to tune our estimates. Sources of error such as the arbitrary selection of pixel values for classification groups of TM band 5 and the arbitrary selection of pixel values in the TM band 4 land/water mask were reduced by conducting repeated trials until a best fit was observed, but this does not eliminate the possibility of error. Areas where this analysis was particularly weak or inconclusive were along shallow shorelines. Without additional data such as sources of oil or other field ground-truth data in estuarine or riverine environments, the pixel values in these areas are difficult to differentiate from other land features.

Overall, this analysis completed the intended objective: a reasonable percentage of area affected by oil spills was obtained from oil slicks on water that were otherwise difficult to discern with the unaided eye and to measure due to the dispersion of oil in water.

Sources

Baumann, Paul R. “ENVIRONMENTAL WARFARE: 1991 PERSIAN GULF WAR.” State University of New York College at Oneonta, 2001, employees.oneonta.edu/baumanpr/geosat2/Environmental_Warfare/ENVIRONMENTAL_WARFARE.htm.

Wallin, David. “Lab II: Environmental Warfare in the Persian Gulf.” Western Washington University, 11 Jan. 2017, myweb.facstaff.wwu.edu/wallin/envr442/ENVI/442_lab2_ENVI.html.