James McArdle
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Natasha Antonova
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Classification of Oil in the Persian Gulf in 1991

Abstract

In 1991, the Iraqi government opened a valve as an act of environmental warfare spilling a more than substantial amount of oil into the Persian Gulf. As the spill had a number of environmental and economic consequences on countries bordering the Persian Gulf, including Kuwait and Saudi Arabia, agencies of these countries acted quickly to minimize the damage. In this study the main objective is to provide insight in how to determine the location and size of the spill using remote sensed Landsat Imagery in order to best concentrate resource use when cleaning up the spill. This study used a technique known as Density Slicing to classify the coverage type and create pseudo-color image. In addition, a land/water mask was applied in order to isolate any oil slicks within the Persian Gulf. The results successfully located and classified the oil spill (heavy or light). While successful, more analysis could be performed in order to further verify the correct location and extent of the oil slicks.

Methods

Data Used:

For the purposes of this study, an 8 bit Landsat Image of the Saudi coastline of the Persian Gulf. The image is comprised of 512 x 512 pixels, detailing an area where much of the oil was spilled. The file contained 7 Landsat bands recording parts of the electromagnetic spectrum that were used in the analysis. All processing was done using ENVI.

Analysis:

The analysis followed what was mandated by the Antonova and Wallin website. First the image was analyzed using TM Band 5 as seen in Figure 1. This allowed for the oil slicks to reflect much brighter than the water and thus isolated themselves from the rest of the gulf. A Density Slice was then applied to further classify the coverage type. After examining the histogram it was determined to break the image into 4 color slices based on reflective values of water, light oil, heavy oil, and land as seen in table 1.

Table 1:

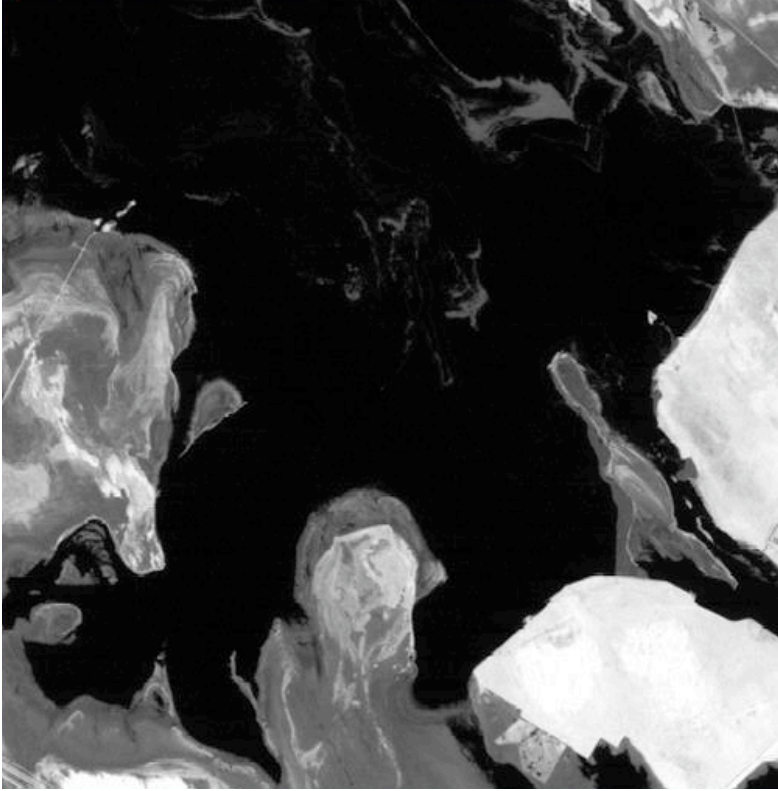| Coverage Type	Color	Slice Minimum	Slice Maximum
Water	Blue	0	25
Light Oil	Orange	26	65
Heavy Oil	Yellow	66	80
Land	Green	81	182

Figure 1.

Figure 2: TM Band 5 Landsat Image of the Saudi Coastline

The data in the histogram pointed to three distinct sets of reflective values with water being the least reflective, followed by oil, and then land being the brightest. The values for the oil was then split based on the assumption that the heavier oil would have a higher reflective value. To eliminate an classification of oil or similarly reflective values on land, a land/water mask was made using TM Band 4 due to this band's characteristic of not reflecting oil. A threshold value of 25 was decided as the point to separate water and land.   Once the image of the mask was produced it was added to the original TM Band 5 image using Band Math, multiplying the values in the TM Band 5 image with the values in the TM Band 4 Image.
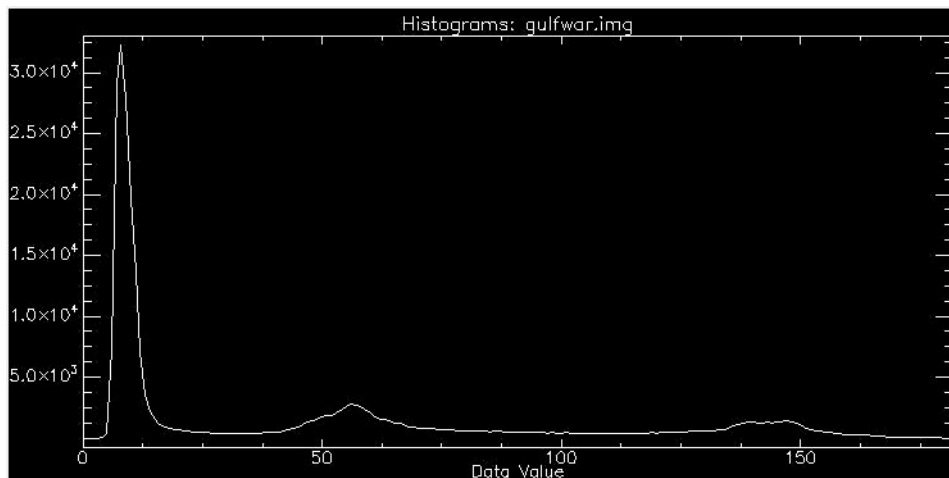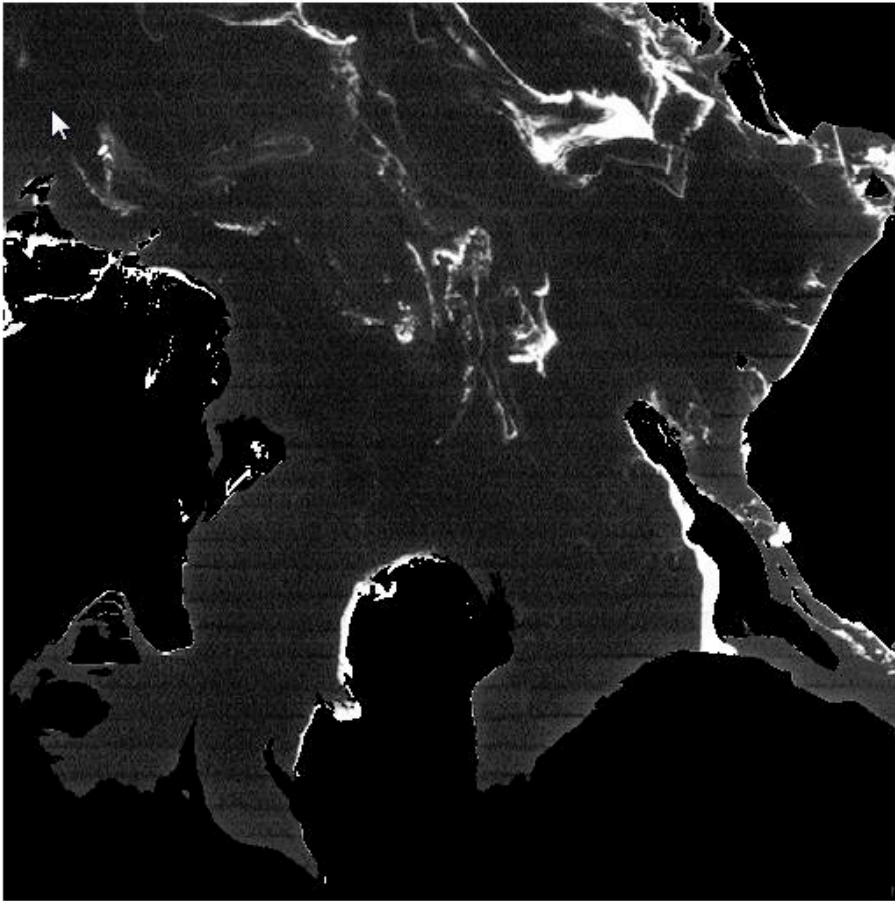
Chart 1: Histogram of TM Band 5

Figure 2.

Figure 2. TM Band 5 with an land/water mask as a result of multiplying the values of TM Band 4 and TM Band 5

The masked image containing the multiplied values of TM Band 4 and TM Band 5 were broken into density slices once again, this time with the Land Cover assigned a value of 0 and water 1-25. This essentially eliminated any light or heavy oil that would have been on land. (Antonova and Wallin, 2014)

Results

The results of the stretched and density sliced TM Band 5 produced four distinct classifications of land, light oil, heavy oil, and water. Each was given a corresponding applicable color so that the results could be viewed and analyzed with distinct clarity.
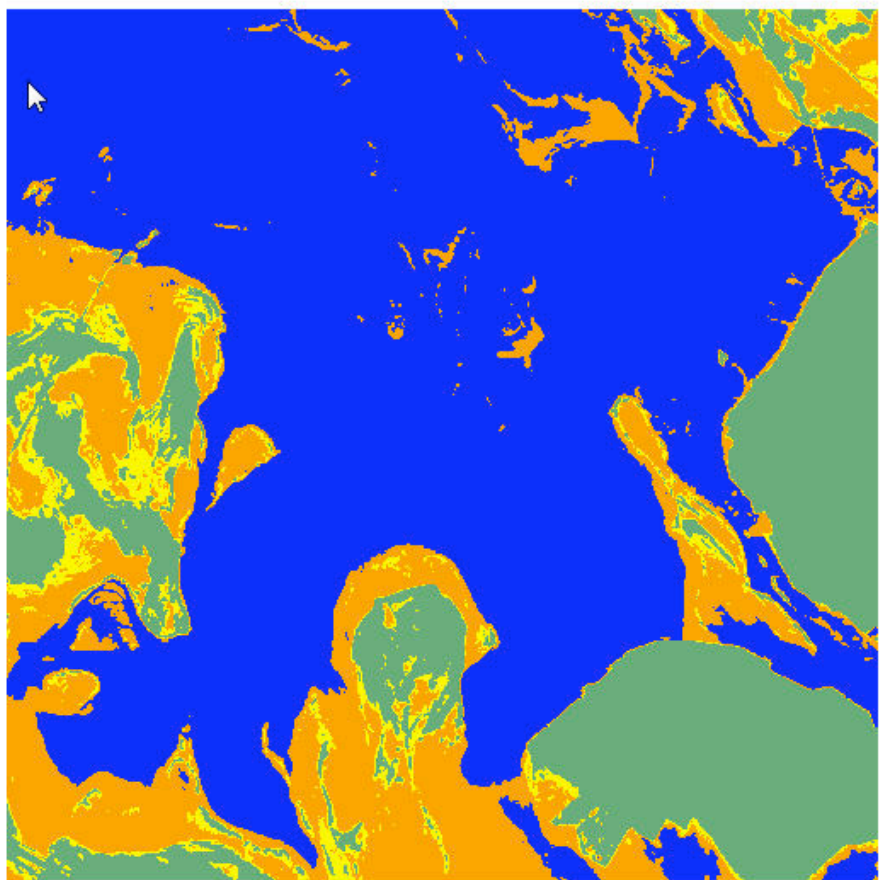
Figure 3.

Figure 3: Pseudo-Color Density Slice of TM Band 5

■ **Water**
□ **Light Oil**
□ **Heavy Oil**
■ **Land**

As can be seen in the figure above while much of the light oil appears to be in the middle of the Gulf, a great amount of the heavy oil and some of the light oil is in areas that could be on land when compared with the original non density sliced image of TM Band 5. Given that the image is viewed in infrared it is clear that the oil resonates brighter than the water, but it can at times be difficult to discern the proper threshold value to differentiate between land and oil, as some of the land may have similar reflective values. The table below demonstrates that land makes up a small percentage of the image (only 19%) with the combined values of light and heavy oil consiting of over 22% of the map. Overall the image shows the geograpic placement of the various cover types, in which the values can be seen in Table 2.

Table 2. Density Slice of TM Band 5

DN Value Range	Coverage Type	# of Pixels	Total Hectares	Percentage of Area
0 to 25	Water	151,311	13,617.99	57.721%
26 to 65	Light Oil	47,450	4,270.50	18.101%
66 to 80	Heavy Oil	11,843	1,068.57	4.518%
81 to 182	Land	51,540	4,638.60	19.661%

Due to the lack of clarity discerning land from oil, the mask discussed in the methods was applied to the image. The subsequent results can be seen in Figure 4.

Figure 4.

Figure 4. A Masked Pseudo-color density slice of the product of the values of TM Band 4 and TM Band 5.

- **Water**
- **Light Oil**
- **Heavy Oil**
- **Land**

The image above displays the water, land, light oil, and heavy oil. Much of the heavy oil seen in the unmasked image is now not visible, with the exception of a few isolated pixels. Much of the light oil has been reduced as well, as the masked filter valued many reflective pixels as 0 due to the multiplication of Band 4 and Band 5. The breakdown of the image can be seen in Table 3.

Table 3.

DN Value Range	Coverage Type	# of Pixels	Total Hectares	Percentage of Area
1 to 25	Water	144,043	12,963.87	54.948%
26 to 65	Light Oil	8,024	722.16	3.061%
66 to 80	Heavy Oil	15	1.35	0.006%
0 to 0	Land	110,055	9,904.95	41.983%

Discussion

The results above validate the methods used. The objective of the study was to determine the location and extent of the oil that had been released into the gulf. Through analysis of remote sensed images this information has been obtained. This is not to say this method is without bias or inaccuracy. The determination of the threshold values breaking the image down into land, water, and heavy or light was subjective to the analyst performing the study. A more accurate method could be performed which would have more accurate results in distinguishing the cover types, especially in deciphering the difference between heavy oil and land. If the methods used had been less subjective and more accurate we would not have seen a reduction of over 4% of heavy oil DN values and a reduction of over 15% in light oil values. This reduction does validate the use of the land/water mask, but also calls into question the original threshold values of the analysis of the TM Band 5 image. Perhaps an unsupervised classification technique or type of clustering could be run on the image to ascertain a better range of values to determine which cover type is oil. In either case, or the way the study has been run, the objectives have been achieved and the location of the oil has been discovered. In many ways the pixels which may lie on either side of the threshold are not as relevant, as the large swaths of oil are clear and distinct. This would allow agencies to respond to largest and most significant portions of the spill, and devote the majority of the resources in this area. If these portions of the spill were contained and cleaned, then attention could be paid to the areas of the image where the pixel verification could come into question. This does lead into one possibility in further breaking down and classifying the DN values which were deemed to be oil and examining and prioritizing areas based on the DN value.

Literature Cited

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