WATER-QUALITY ASSESMENT IN THE İZMİT BAY USING LANDSAT-TM IMAGE DATA

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ABSTRACT : *The paper deals with the evaluation of the water-quality in the İzmit Bay with the LANDSAT-5 TM data acquired on 12 June 1984. Because of not having the sea-truth measurements, the technical reports related to water-quality and distribution of the pollution sources in the studied area are taken into consideration for interpretation. Classification algorithms are applied to both different band combinations and ratios.*

0. INTRODUCTION

İzmit Bay, located on the northeastern part of the Marmara Sea, has a surface of approximately 310 km^2. It is an elongated semi-enclosed body of water about 50 km in length and 2-10 km in width and considerable depth except for the eastern part. Some physical properties of the three distinct regions separated according to its topographic and oceanographic characteristics are tabulated in Table 1 [1]. In this study, the most polluted area between geographic coordinates 29° 40′ - 29° 50′ longitudes east and 40° 38′- 40° 50′ latitudes north is selected for the examination (Figure 1).

Table 1 : Basic physical characteristics of the İzmit Bay.

Region	Length km	Width km	Maximum depth, m	Surface area, km^2	Volume km^3
Eastern	16	2-5	35	44	0.85
Central	20	3-10	180	166	12.42
Western	17	3-5.5	250	100	?

As its hydrographical characteristics, the Bay is influenced to a large extent by the water exchanges taking place between the Black Sea and Aegean Sea. Although the Bay dictates a permanent two-layer stratification throughout the year, the degree of stratification and the characteristics of water masses show considerable inter annual variations, particularly in the upper layer. During the spring-summer period, less saline waters of the

Black Sea origin flow into the Bay. A compensatory lateral westerly outflow takes place mainly in the surface layers particularly during the April-June period. After June, high saline waters of the Marmara flow into the bottom layer of the Bay. It thus, results in a net salinity and temperature increases at 15-35 meters in depth, as well as considerable changes in biochemical parameters. The natural color band combinations of the area examined are given in Figure 2.

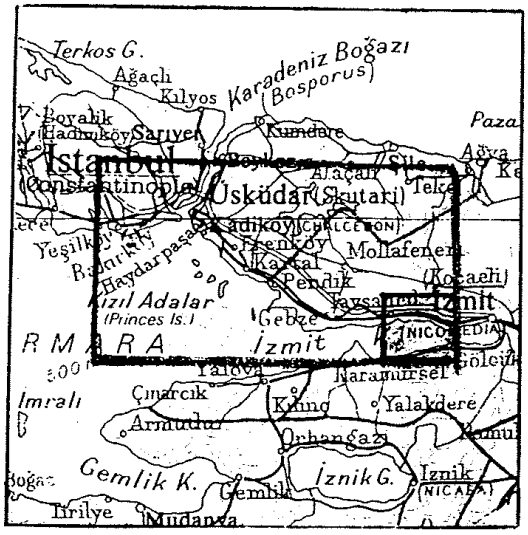

Figure 1 : The coverage of the LANDSAT-5 TM used and the location of the studied area on a map at 1 : 50 000 scale.

Figure 2 : The natural color image of the area examined.

1. TECHNICAL REPORTS RELATED TO WATER-QUALITY

İzmit Bay is perhaps the most characteristics zone in Turkey where the extend of pollution increased mostly in recent years, at escalating rates beyond tolerable levels. A

wide-spread growth of large spectrum industrial activities, ranging from pulp and paper to petrochemical from food to metal processing and fertilizer industries have increased the pollution problems due to their large volumes of liquid and solid wastes **[2]**.

According to scientific and technical studies done in this area, polluting sources can be outlined as follows :

1. Domestic waste water discharges.
2. Waste waters from industrial activities.
3. Domestic and industrial solid wastes.
4. Pollution through the streams to the region.
5. Surface run-off from agricultural areas.
6. Pollution by air-sea interactions.
7. Pollution created by navigational activities.
8. Hydrographic interactions with adjacent water bodies.

Organic loadings from industrial sources to the receiving waters are about four times larger than those originated from domestic waste water discharges. Pollutants such as, nitrogen, phosphorus, and fluorine compounds from fertilizer plants have also important polluting potential, since nitrogen and phosphorus are responsible in many cases from promoting eutrophication resulting excessive algal growth and red-tide events. In addition to those land-based polluting sources, there is a great deal of shipping traffic which is also considered potential polluting source for petroleum hydrocarbons. On the other hand, special and hazardous wastes such as pesticides, toxic chemicals and heavy metals from various sources are effective on the ecology of receiving waters.

When examining the sources, water circulation in the summer period and bottom topography should also be taken into consideration (Figure 3 and 4). As can be seen from the Figure 3 which shows approximately observed horizontal circulations within the regions of the Bay, the surface waters flow into the Bay as the lower waters flow in the westerly direction and join finally to the open sea along the northwestern coast of the outer region.

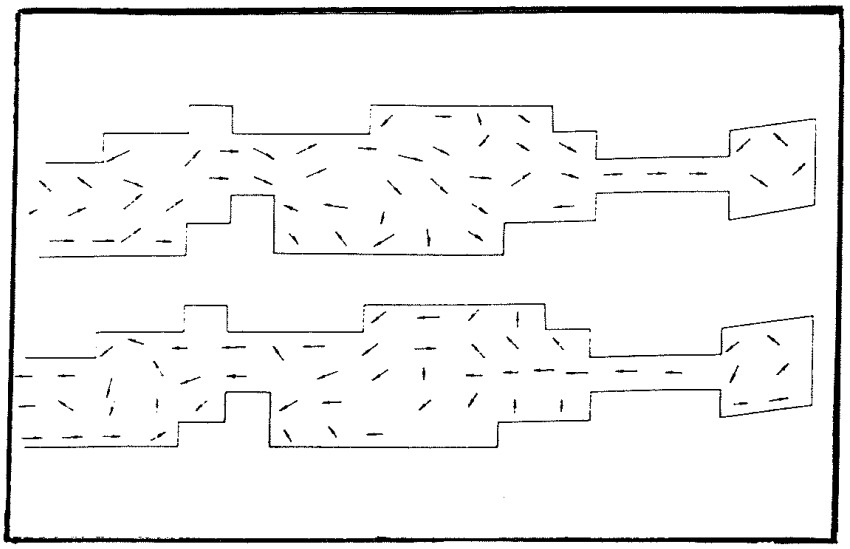

Figure 3 : Upper and lower layer summer circulation paterns **[3]**.

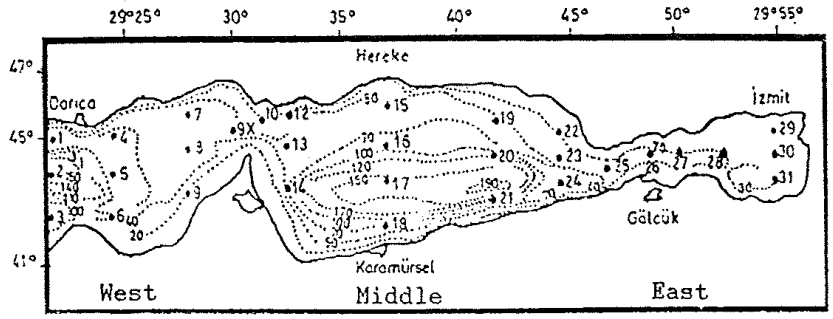

Figure 4 : Bottom topography of the İzmit Bay.

2. BASIC FEATURES OF THE ALGORITHMS USED

In the classification, the Euclidean Distance, the Gauss Maximum Likelihood and the Linear Discriminant Function classification algorithms which are available in the DISIMP software program have been utilized. For these classification algorithms, the training areas have been selected according to their color tones and the hydrological characteristics of the area because of not having the sea-truth measurements concident with the day image taken. In the Euclidean Distance classification algorithm, a pixel of unknown identity are being to classified by computing the distance between the value of the unknown pixel and each of the category means **[4]**.

$$E = \left(\sum_{i=1}^{n} (x_i - y_i)^2 \right)^{1/2}$$

n = Dimension (Band)
E = Distance between the spectral values of the picture elements in n-dimensional space.
x,y = Spectral values of picture elements in n-dimensional space.

After computing the distance, the unknown pixel is being to assigned to the "closest" class. If the pixel is farther than a Euclidean distance specified from any category mean, then it is being to classified as "unknown". The Maximum Likelihood classifier quantitatively evaluates both variance and covariance of the category spectral brightness values under the assumption that the distribution is Gaussian (normally distributed). Then to classify an unidentified pixel, the probability of pixel value belonging to each category are being to calculated and then assigned to the most likely class (highest probability value) or labeled "unknown" if the probabability values are all below a threshold specified **[5]**. Especially in multi-channel classification, the Linear Discriminat Function algorithm which also gives similar classification result with the Gauss Maximum Likelihood algorithm is more effective and faster. A discriminant function that is a linear combination of the components of X is as follow :

$$h(X) = V^T X + v_o \lessgtr 0 \longrightarrow X \in \begin{cases} w_1 \\ w_2 \end{cases}$$

The term h(X) is a linear function of X, V^T is the linear discriminat function coefficients and v_0 is the threshold value. In this method, the discriminant functions for class pairs are determined according to the coefficients and threshold value which are calculated iteratively for class pairs and minimized the error probability. Then, according to its function value, any pixel in the image is assigned to w_1 if $h(X) > 0$ and w_2 if $h(X) < 0$.

3. APPLICATION OF THE ALGORITHM TO THE AREA SELECTED

The image of the selected area contains 512 x 512 pixel data. The spectral histograms which show the spectral distribution of the data are given in Figure 5. Because of the spectral differences between the spectral bands (Figure 5), the classification algorithms used are applied not only original but also ratio data. To increase the visual distinction between the features in the scene, the algorithms are applied to the contrast manipulated band combinations.

From the literature, it is observed that the image data, especially belonging to the band 1-4 are highly correlated with the water-quality data. But for this study, the infrared bands (Band 4 and 5) also gave satisfactory results for the interpretation. Also the combination consists of all bands (except Band 6) is taken into consideration (Figure 6, 7, 8).

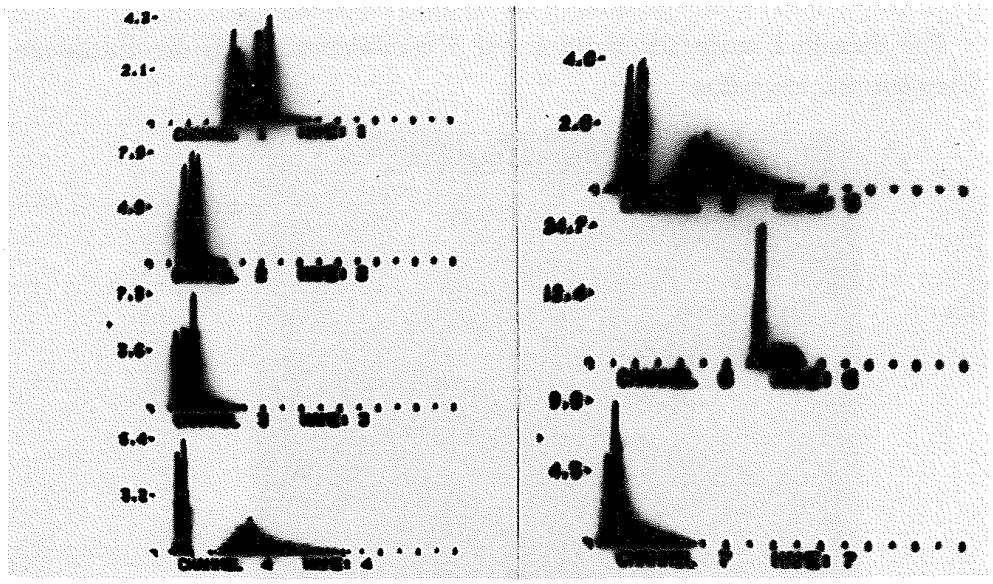

Figure 5 : Spectral histograms of the area selected.

Figure 6 : The classified image for Band 2 and 3 combinations with the Maximum Likelihood Classification algorithm.

Figure 7 : The classified image for Band 4 and 5 combinations with the Euclidean Distance Classification algorithm.

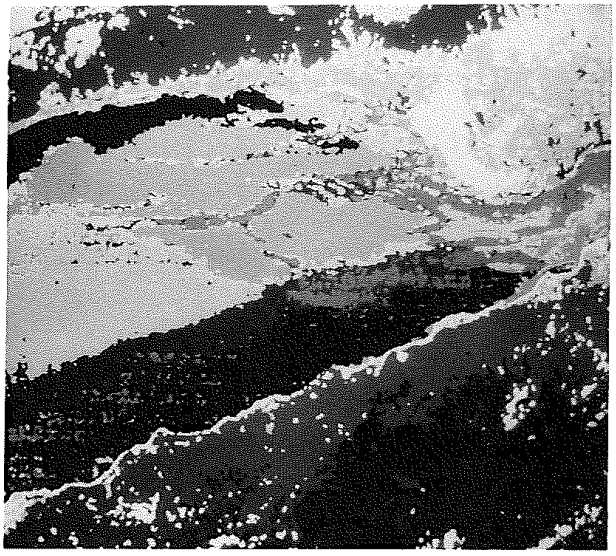

Figure 8 : The classified image for all band (except Band 6) combinations with the Linear Discriminant Classification Algorithm.

In the classified images presented above, it can't be possible to interpret which class belongs to which pollution parameters due to not having sea-truth measurements. But in all images, it is seen that due to water circulation, the surface water flows in the southernwestern coast of the Bay carries the accumulated waters in the eastern part of the Bay which has limited self-purification capacity due to its lower water volume and long residence time of waters in the region. As it can be seen from the original image (Figure 2), polluted waters flow from the eastern part to the center along the northeastern coast. To show this result, next image frame towards to the west part of the Bay is also classified (Figure 9). Altough it is possible to coincide the classified images with the technical reports, to get more reliable results and to increase the classification accurucy, it is necessary to select the training areas according to sea-truth measurements.

Classification results obtained from band ratio images don't add any further information to the above results achived from the original data and thus are not presented here in detail.

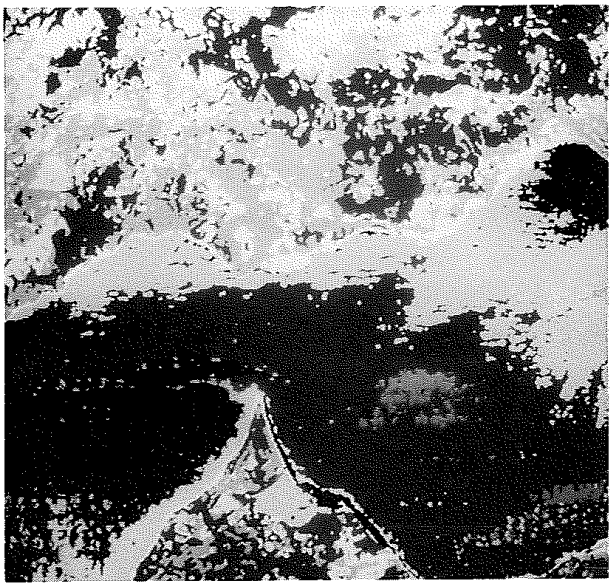

Figure 9 : The classified image of the next image frame towards to the west part of the Bay for all band (except Band 6) combinations with the Linear Discriminant Classification Algorithm.

4. RESULTS

Pollution is generally most severe in semi-enclosed marginal seas and coastal waters bordering highly populated and industrialized zones like the İzmit Bay. Due to its biological selfpurification capacity is no longer sufficient to prevent the damages of water resources and natural ecological property of the Bay itself, the remote sensing methods applied to find out optimal solutions in water-quality management in terms of efficiency and economy. Although, the deficiency of the the sea-truth measurements coincident with the day image taken and the complex nature of the phenomenon affecting the water in the natural systems, it is shown that it is possible to determine the different spectral reflectance paterns and provide a reasonably good estimate for the evaluations of water supply which is a topic that must concern everyone on the surface of this planet.

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