Examination of the Pollution in the West Black Sea By Remote Sensing Technologies

Uzaktan Algılama Teknolojileri Kullanılarak Batı Karadeniz' de Kirlilik İncelemesi

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Abstract:

Black Sea has been subjected to various investigations from the 19th century to the present time, due to its unique oceanographic features and geological evolution. It has a surface area of 423 000 km^2 (excluding the Azov Sea) and a volume of 547 000 km^3. The Black Sea (BS) is an intercontinental and is almost a miniature ocean with its geological structure. Unlike other seas of the world, the BS shows unique quality and trophic properties. Fortunately, only the upper layer water of the BS is introduced into the Strait of Istanbul (SOI; Bosphorus) and has a significant effect on the quality and trophic conditions of the Marmara Sea (MS). These effects are discussed in the light of data obtained from collaborative efforts of processed satellite images and various research institutions.

Keywords: Black Sea, Danube River, Remote Sensing, Strait of Istanbul, Marmara Sea.

Introduction

Oceans cover more than two-thirds of the Earth's surface. They have a very important influence on global climate, weather and circulation. But still human have little information about oceans and their processes. The ocean itself is a complicated system with movement and variability at all time and space scales (Robinson, 1985). The scientific understanding of the ocean process depends upon being able to measure the wide variety of variable parameters which describe the sea. (Summerhayes and Thorpe, 1996). Remote sensing technologies have been used for identification of ocean processes and global hydrodynamic processes in seas. Oceanographers and environmentalists need objective, rapid and accurate methods to track features in satellite images in order to estimate surface circulation.(Emery, 1986). Remote sensing techniques provide an instantaneous survey of a given spatial domain which is impossible to obtain by classical contact techniques, a series of instantaneous surveys at different times. (Nihoul, 1984). Remote Sensing technologies has proven to be a cost effective monitoring and measurement tool in many environmental applications. In addition to remote sensing technologies which have already been used in oceanographic studies in several parts of the world since the 1960's (Robinson, 1985; Zainal et al., 1993). Global view and wide spatial perspective have been a new branch of oceanography since the first application of remote sensing technologies (Summerhayes & Thorpe, 1996). Oceanographic data and satellite imagery are used to describe the structural variability, the circulation and the water quality of oceans (Oğuz et al., 1992).

A number of satellite systems and platforms are used to obtain information about ocean processes. Different information about the oceans and its processes is carried by different frequencies of electromagnetic waves, with the result that particular sensors are associated with particular oceanographic parametres.(Robinson, 1985). Spaceborne platforms which are dedicated for remote sensing applications, have sensors which are working in different ranges of the total electromagnetic spectrum.

Study Area

The BS catchment basin with an area of 2.5 million km^2 extends to Central Europe through the Danube River in the West; to the Baltic Sea in the North; to the Caspian Sea in the East and Central Anatolia in the South. There are six countries along the cosat of the BS, however the catchment area consists of seventeen countries and a population of 165 million and is five times larger than the sea surface area. In spite of this large basinal area, its connection to the ocean is rather limited. It is connected to the Aegean Sea (Mediterranean Sea) by way of the Turkish Strait System

(TSS) including SOI, the MS and the Strait of Canakkale (SOC; Dardanelles). The existence and characteristics of MS are closely related to the BS due to its direct communication throu ws into the MS via the SOI (Figure 1). In addition to it is absolutely necessary to determine the contribution of the BS to the quality of the MS in order to completely understand the whole of the extremely complex processes before developing Istanbul's and other cities which are located surrounding of the MS' s wastewater disposal strategies. Istanbul, with its settlement area of 79.780 ha, has a population of around 10 million and is the biggest and most important city in Turkiye. It has been an international centre of attraction since ancient times because of its location on the strait connecting the BS to the Mediterranean Sea via the MS (Gönenç et al.,1995).

During recent years the quality of river and sewage waters delivered to the BS has been dramatically changed, the distribution and concentration of biogenic element, heavy metals, pesticides, detergents, etc. has increased (Polikarpov, et al.,1991). The growing pressure of population and industrial activities in a such a large catchment basin increase the anthropogenic influences and pollution in the BS. The most intensive effects of pollution can be observed in the Western BS (WBS) which is located between Sivastopal in the North and Inebolu in the South. The WBS is surrounded with the Eastern side of Crimea Peninsula and lower plain plateau of South Ukraine to the North; the Balkan Peninsula (Romania and Bulgaria) and Thrace to the the West and Kocaeli Peninsula (Turkiye) and West Black Sea Region (Turkiye) to the South. The major water input to the BS is provided by the large rivers in its catchment area and high precipitation in the region. The major rivers draining to the BS are Dyneper, Danube, Bug, Dynester, Sakarya and Filyos.

The Danube River contributes approximately 60% of the water input and 20% of the suspended material (24.1 million ton/year) to the BS (Zaitsev & Mamaev, 1997). This sediment load carried by the Danube River is accumulated at the shallow continental shelf. Domestic, industrial wastes and nitrogen, phosphor and pesticides derived from agricultural activities are carried to the BS by the aforementioned rivers. Previous studies concerning the pollution in the BS are mostly in local scale.

Processing of Satellite Images and Field Studies:

Since the launch of first Lansat in 1972, Multispectral Scanner (MSS) data have been used in a range of seas and lakes oceanographic investigation and water quality assessment activities. The wealth of experience gained using MSS data for the purpose is well documented (Scarpace et al.,1979;

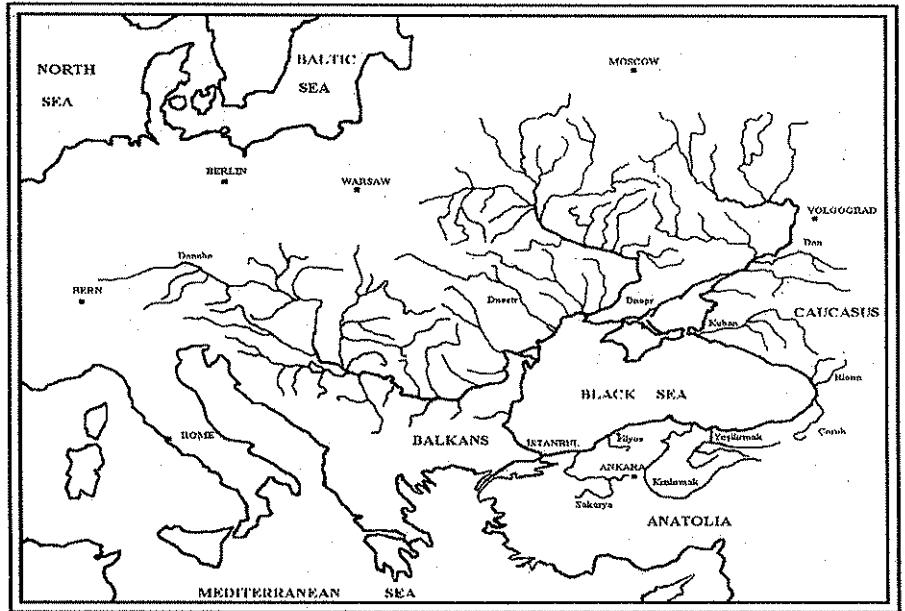89

Figure 1. Catchment Area of Black Sea (*Modified from* Müller & Stoffers, 1974; Algan *et al.,*1998)

Moore, 1980; Witzig and Whitehurst, 1981; Lillesand *et al.,*1983; Charpenter and Charpenter, 1983; Lindel *et al.,*1985; Verdin, 1985; Zainal *et al.,*1993; Brockmann, 1994). With the launch of Landsat 4 and 5 in 1982 and 1984, respectively, water resource managers have access to Thematic Mapper (TM) data in addition MSS data. The geographic area covered by both the MSS and TM sensors is same, the TM has greatly improved spatial, spectral and radiometric resolution. Since 1982, other than MSS data, TM data also ensured a background and experience on oceanographic researches and water quality (Lathrop and Lillesand, 1986).

Firstly, the approximate locations of monitoring stations and alternative dates were determined for the marine investigations in this study. For simultaneous data of field and satellite images, compatibility of these dates with the program of Landsat and suitability of meteorological conditions had been considered as the first critea. Secondly, an evaluation of the monitoring stations previously employed by various national groups for water quality assessments, that are located north and south the Danube River, and north and south the SOI was accomplished for the selection of the stations to be used in this work (Gönenç *et al.,*1995). The same criteria had also been used for the determination of the number and location of stations and monitoring data on the Danube River. Measurement and

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sampling depths had been chosen to reflect the characteristics of the upper layer of the BS. Parametres to be measured and analysed had been selected to characterise the physical, chemical and microbiological pollution and the ecological structure.

In this study Landsat TM, Track Ref. No: 180/29 (Danube River), 180/30 (Bulgaria), 180/31 (Turkiye) are used.

Results and Discussion

Satellite data: Landsat TM Band 2 *(0.52-0.60 μm, visible green wavelengths)* for chlorophyll-a; TM Band 3 *(0.63-0.69 μm, visible red wavelengths)* for suspended solids; TM Band 6 *(10.40-12.50 μm, is in the thermal portion of the spectrum and used for thermal mapping and also used to verify surface flows)* (Jensen, 1986), are used. TM B3 and B1 are processed together for the interpretation of suspended solid distributions (Figure 2); TM B2 and B1 are processed together for the interpretation of chlorophyll-a (chl-a) distributions (Figure 3) (Bhargava and Mariam, 1991). TM B4, B3 and B2 are processed together to estimate turbidity distribution (Figure 4). TM B6 is used for thermal mapping and verify surface flows (Figure 5).

Physical data: An examination of the vertical and horizontal sea water temperature distribution shows that thermocline lies between 10-30 metres in the summer and autumn. The Danube River itself, as well as the seasonal variations, has effect on these depths. In general from the Danube River to the SOI, the temperature of the sub- thermocline water does not change. However, at locations close to the SOI, a temperature increase below 50 metre is observed upon the impact of the Mediterranean water. Above the thermocline, temperature drops by the degrees observed from the Danube River towards the SOI. Although some variations along the Romanian coast due the impact of the Danube River exist, halocline depths are found to occur between 10-100 m. Along the Turkish coast, towards the SOI the effect of the Mediterranean water becomes more and more obvious in the sub halocline water. Above the halocline salinity shows small increases some what in autumn as compared to summer due to decrease of river flows in autumn. An evaluation of the parameters repenting light penetration, i.e., Secchi disc depth, total suspended solids and turbidity, shows that the effect of the Danube River on these parameters is very significant. The variation in those parameters decreases as one moves away from Danube River. Secchi disk depth is between 3-9 metres along the Romanian coastline while it is 6-8 metre near the SOI. The very high Suspended Solids value attained along the Romania coast is attributed to the Danube River (25 mg/l and 18 mg/l DOWN TO a depth

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of 30 m., as the average of summer and autumn, respectively) (Gönenç *et al.*,1995; Gönenç *et al.*,1996).

Chemical Data: It is taken for granted that the hypoxic conditions starting below 50m. of depth in the BS quickly transform into anoxic conditions after this depth. In the coastal water from Danube River to the SOI moving the SOI, the sudden decrease of oxygen in the lower layer is attributed to the Mediterranean water. When these variations are evaluated in terms of oxygen saturation, it may be concluded that, above the pynocline, oxygen is around the level of saturation due to photosynthesis, and below the pycnocline, oxygen moves rapidly away from the saturation level due to the biochemical oxidation of detritus. The reason for the reduction of oxygen production towards the SOI as opposed to high oxygen production levels due to photosynthesis in the coastal zone under the effect of the Danube River and counting oxygen consuming processes towards the SOI acting to deplete the oxygen content.

From the Danube River to SOI, the reductions observed in pH, especially at almost all depths and all stations during the autumn provide further confirmation for the interpretations above. The reduction in pH may also explain and by the balance in CO_2 production and consumption during photosynthesis and oxidation. In the layer above the pycnocline, excessive CO_2 consumptions occur due to high levels of photosynthesis. This is especially true for the coastal zone around the Danube River. On the other hand, in the layer below the pycnocline, CO_2 is produced continuously due to the high level of bacterial activity. Reduced photosynthetic activity towards the SOI reduces CO_2 consumption. pH values below 7, observed towards the SOI especially below 100 metres of depth, is a result of the biochemical reactions going on in the anoxic zone.

Nutrient distributions from Danube River to the SOI are typical indicators of photosynthetic activities and discharges. Daily inorganic nitrogen discharge of the Danube River into the BS is at an average of 2 000 tons, as opposed to 100 tons of discharge via lower layer SOI water into the BS. If it is assumed that the amount of nitrogen is gradually reduced, in part due to photosynthetic activity, by a factor of 5 to 10, the amount of nitrogen introduced into the MS from BS via the SOI is expected to be around 200 tons per a day. Ammonium concentrations ,n the upper layer that are below detectibility limits at times show a rapid increase in the lower layer due to the decay of the detritus in the anoxic zone. Nitrate concentrations that increase rapidly towards 50 metres decrease considerably after this depth paralleling the increase rate of denitrification in the anoxic zone. Additionally, about 200 tons of phosphorus and 2 000 tons of silica are discharged into BS daily via the Danube River: Daily

phosphorus and silica loads from the lower layer Mediterranean water into the BS are 40 and 1 000 ton, and the phosphorus and silica loads from the upper layer of the BS into MS are 20 and 200 tons per day respectively.

With these evaluations it is possible to say that, like other seas, nitrogen is the limiting nutrient in terms of eutrophication in the BS (Gönenç *et al.,*1995; Gönenç *et al.,*1996).

Microbiological Data: Measurements of coliform at the surface indicate that the pollution around the coast affected by Danube River reaches levels that pose a threat public health. However, coliform levels reduce gradually towards the SOI.

Ecological Data: The following evaluation is based on a detailed plankton analysis conducted from the Danube River to SOI. As can be seen image (given Chl-a distribution) and mass phytoplankton were both observed to significantly higher in the autumn in comparison to the summer (Figure 3). However a reverse trend was seen for zooplankton. No algal blooms were detected during the study period. The amount of zooplankton feeding on phytoplankton increases towards the SOI, reducing the amount of the latter. Considering the total amount of planktonic biomass, a significant decrease is observed from Danube River towards the SOI. Phytoplankton and zooplankton numbers and masses vary with depth in all stations. Phytoplanktons are concentrated in the upper layer, especially in the first 10 metres. Their concentration decreases 100 times at a depth of 50 metres. In contrast, zooplanktons are mostly located between depths of 10-25 metres (Gönenç *et al.,*1995; Gönenç *et al.,*1996).

Conclusion

Results of satellite data classification, distribution of Chl-a and suspended sediment concentration decline from to Danube to Turkish coast (Figure 3 and 4).

The BS has been controlling the ecological structure in the MS through nutrients and planktons it introduces into the latter. On the other hand within the degradation process of detrius, generated in the MS as a result of planktons produced due to the input both from the BS and from land based pollutants including Istanbul, the nutrient level increases in the hypoxic and anoxic zones. Nutrients so formed are then returned to the BS via the bottom layer through SOI.

The growing pressure of population and industrial activities in a such a large catchment basin increase the anthropogenic influences and pollution in the BS. The most intensive effects of pollution can be observed in the WBS. The major water input to the BS is provided by the large rivers in its catchment area and high precipitation in the region. The major rivers

draining to the BS are Dyneper, Danube, Bug, Dynester, Sakarya and Filyos. The Danube River contributes approximately 60% of the water input and 20% of suspended material (24.1 million ton/year) to the BS. This sediment load carried by the Danube River is accumulated at the shallow continental shelf. Therefore, the Danube delta moves approximately 40 metres to the sea every year.

Özet

18. yy' den itibaren günümüze özellikleri ile birçok araştırmalara konu olan ve kıtalararası bir içdeniz olan Karadeniz, jeolojik açıdan da bir minyatür okyanus özelliği göstermektedir. Havza sınırları başta Tuna Nehri aracılığı ile Avrupa içlerine kadar uzanan Karadeniz' in diğer denizlerle olan tek irtibatı Türk Boğazlar Sistemi ile sağlanır. Karadeniz' deki antropojenik etkiler ve deniz kirliliği giderek artırmaktadır. Karadeniz' de yapılan çalışmalar incelendiğinde, çoğunluğunun yerel ölçekte olduğu gözlenir. Ancak Batı Karadeniz' deki deniz kirliliğinin makro boyutlarda araştırılması gerekmektedir. Bu bağlamda böyle bir çalışmanın yapılabilmesinin en ekonomik yolu uzaktan algılama teknolojilerini kullanmaktır.

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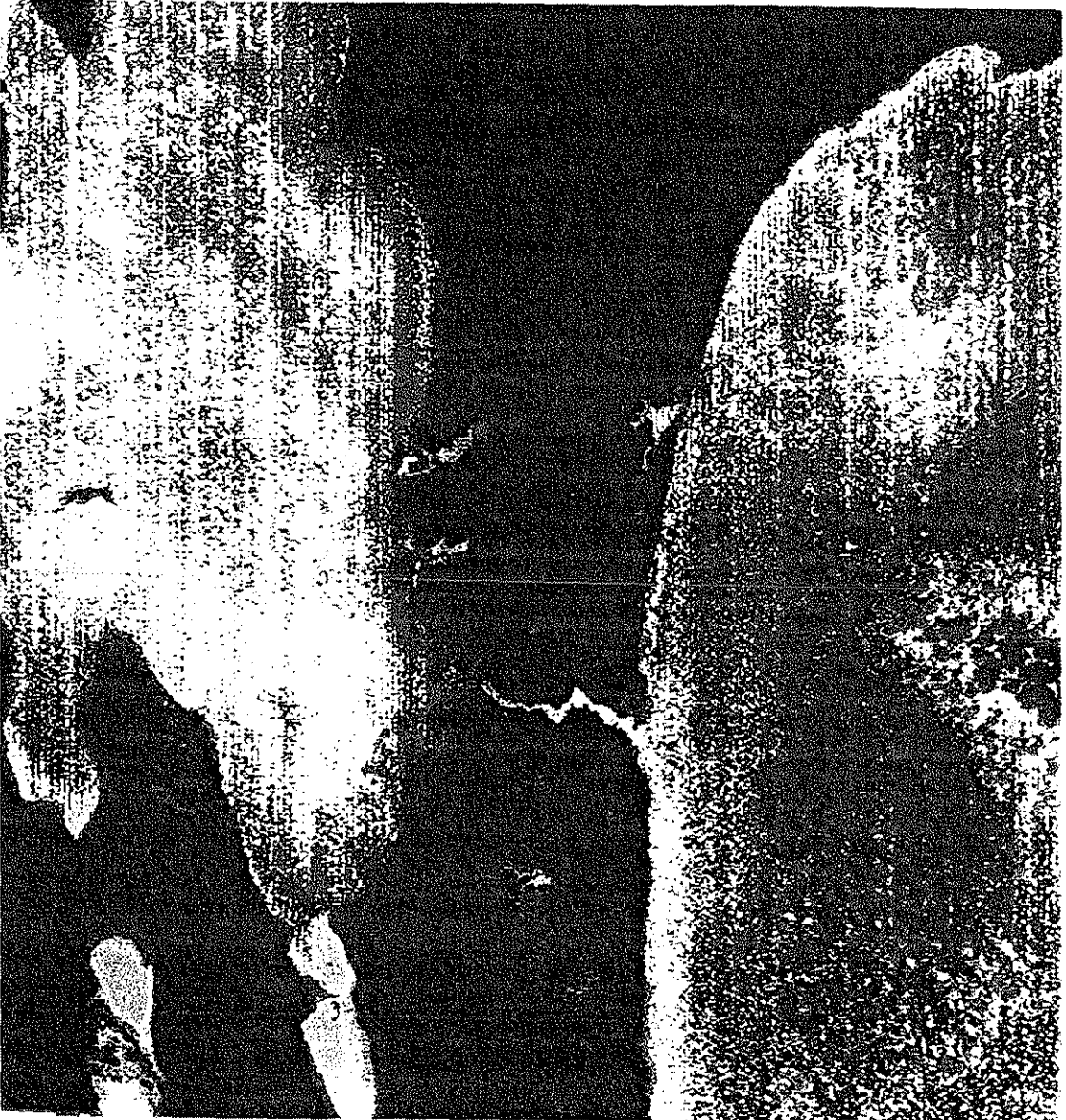
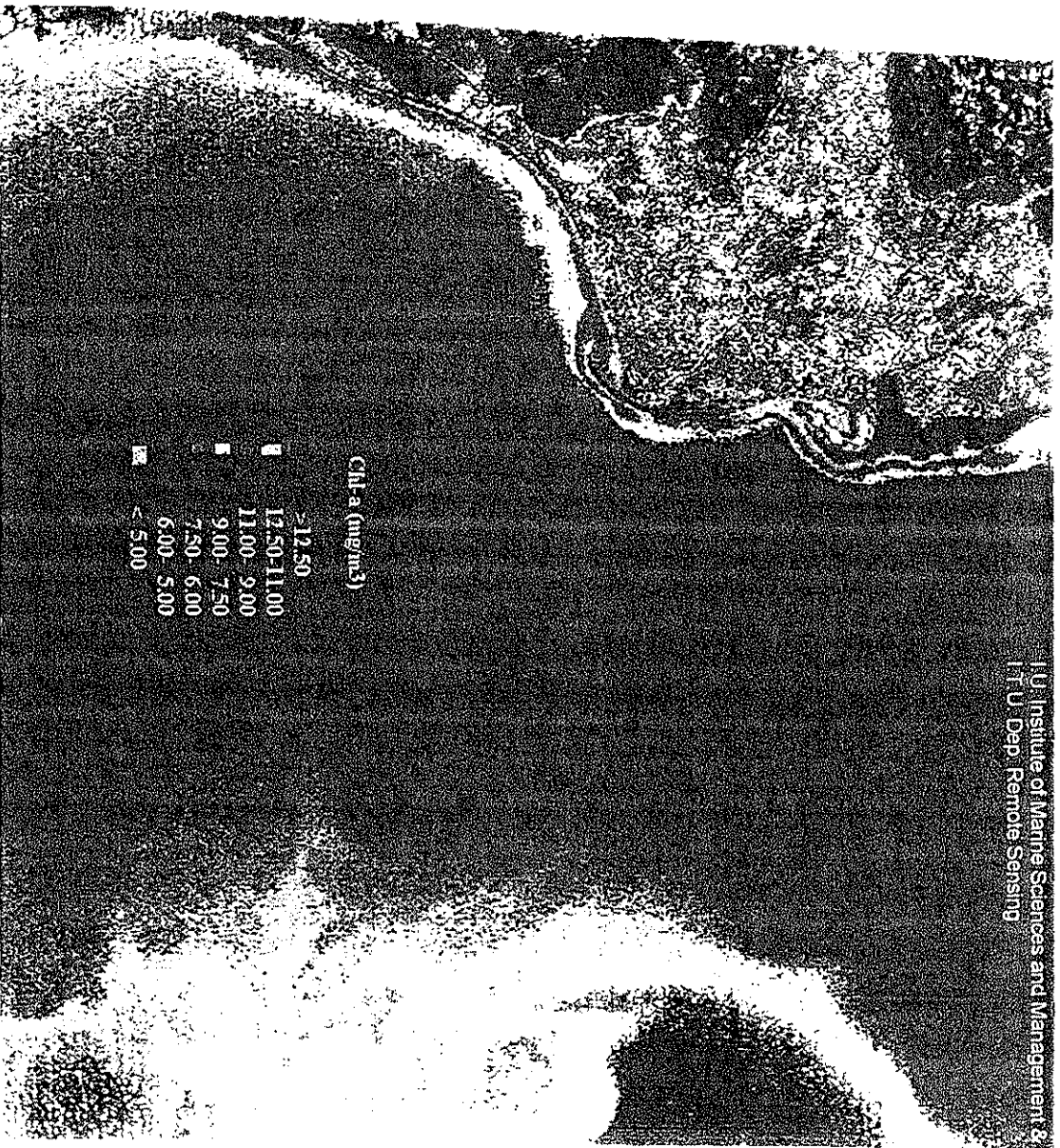Figure 4. The turbidity distribution (1992) at Southwest Black Sea and Marmara Sea (Gazioğlu et all., 1997)

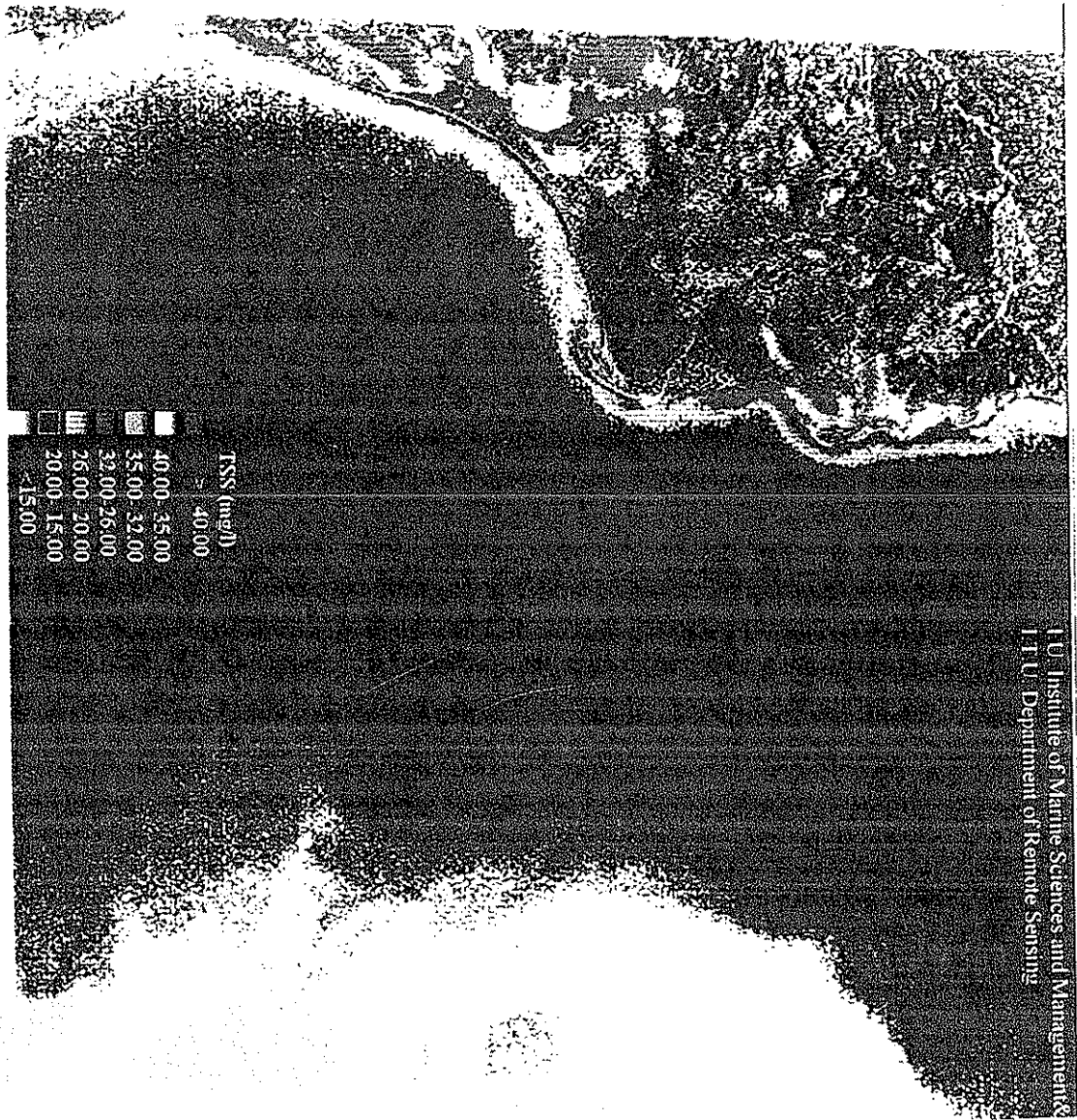Figure 3. The Chl-a distribution (1992) at Danube Delta.

Chl-a (mg/m3)

>12.50
12.50-11.00
11.00- 9.00
9.00- 7.50
7.50- 6.00
6.00- 5.00
< 5.00

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TSS (mg/l)
> 40.00
40.00- 35.00
35.00- 32.00
32.00- 26.00
26.00- 20.00
20.00- 15.00
< 15.00

Figure 2. The TSS distribution (1997) at Danube Delta.

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