AN INVESTIGATION OF INDUSTRIAL PLANT POLLUTION USING SATELLITE IMAGERY AS A TOOL IN ZONGULDAK COSTS, TURKEY

Yıldırım, Y..[a*], Büyüksalih, G.[a], Oruç, M.[a]

[a] Zonguldak Karaelmas University, Zonguldak, Turkey,
yildirim@karaelmas.edu.tr, gbuyuksalih@yahoo.com

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ABSTRACT:

In this study, Landsat-7 ETM+ satellite imagery, dated 04.07.2000, was processed to find out a power plant solid waste effect on the surrounding environment, dispersion in the sea and possible impact on sea life. For this purpose, eCognition v.4.0.6 software was utilized to carry out classification of the sea pollution caused by the industrial plant. Polluted area in the sea was classified into three regions: highly polluted, moderate polluted and less polluted. It was found that highly polluted region covers 5.2 % of the main polluted region, moderate and less polluted region cover 27.2 and 67.6 % of the polluted area respectively. Although the fly ashes are chemically not a hazardous material, it makes physical pollution in the seawater and this may harm the flora and fauna and indirectly food chain in the sea environment.

1. INTRODUCTION

Power production and energy use can bring about significant adverse environmental effects. Economic development and improved standards of living are complex processes because of reliable supply of demanding energy. Energy supplies are key limiting factors to economic growth. On the other hand, environmental awareness is one of the big issues in last three decades and it is growing day by day all over the world. Turkey is at the starting level of industrialization which is reflected by energy production and consumption figures as compared to industrialized nation. Coals and lignite are Turkey's most abundant and utilized fossil fuels for energy production.

Environmental impact of coal fired power plant is a growing problem. Due to low calorific value, high sulfur, moisture and ash content, power plant's fuels are extremely pollutant. In a coal fired power plant, the slag and fly-ash management is one of the main environmental problems.

The ability of space borne instruments to measure the amount of electromagnetic radiation reflected and emitted by the Earth's surface has proved to be valuable for the understanding of our environment. In the interpretation such data, since it is not easy or feasible to survey over the sea by geodetic or other ground methods, we employ remotely sensed data for quantifying and classifying the pollution effects in such environment. In this case, computer-assisted classification which is useful for extracting information that can be exploited for cartographic purposes, such as in the generation of thematic maps of land cover types.

2. LITERATURE REVIEW

Remote sensing applications have been utilized in many different fields. Ram and Kolarkar (1993) used remotely sensed data to analyze land-use changes in various parts of arid Rajasthan (India). They found that net snow area and the net irrigated area has increased, fallows have declined, and forest and pastures become highly degraded. They also highlighted the advantages and limitations of remote sensing and their comparison with traditional methods.

Schultz (1988) used remote sensing to measure indirectly hydrologic data. He used a remote sensing method to measure electromagnetic signals, which can be converted into hydrologic data, to apply real-time flood forecasting in the field of evapotranspiration, soil moisture, rainfall, surface water, snow and ice, sediments, and water quality.

Hirata et al., (2001) employed satellite image processing using geocoded bands 2, 3 and 4 of Landsat 5 Thematic Mapper (TM) images to evaluate total forage resources and to assess human impact in the Abdal Aziz Mountain area in northeastern Syria. They used vegetation classification to categorize rangeland into six classes according to the plant contacts of dominant shrubs and herbaceous plants. They also categorized cultivated fields into two classes.

Ghar et al., (2004) used a maximum likelihood supervised classification employing the Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images on two different dates to monitor agricultural land changes in the Eastern Nile Delta of Egypt. They employed a supervised classification to carry out with the six reflective bands for the two images individually and ground truth data to assess the accuracy of the classification.

Zhou (2001) used remotely sensed data to assess the human impact on the fragile ecosystem of arid environment by monitoring and modeling landuse and land cover change during the last 40-50 years in China. He employed two images for assessment: a Landsat TM image with a ground resolution of 30 meters and the IKONOS multispectral image with a ground resolution of 4 meters.

* Corresponding author

The conservation of marine habitats may serve as a practicable surrogate for conserving other scales of diversity including species and ecosystems. Mumby and Harborne's paper advocates an objective, systematic approach to habitat classification which couples coastal geomorphology and benthic cover. They illustrate their approach with a scheme based on extensive field data from the Turks and Caicos Islands and Belize.

Ishihara et al., (2002) used remote sensing to develop a financially feasible and practical method for monitoring illegal solid waste dumping by medium-resolution sensors (Landsat-TM, ASTER). They employed two methods to evaluate land surface changes: NDVI (Normalized Difference Vegetation Index) method and VSW method.

Zhu and Joao, used remote sensing method for recognition of lakes and other water bodies from remotely sensed imagery. They employed two types of Landsat images as sample images in order to test the performance of the algorithm. The first one is RGB images generated from the composition of Landsat Bands, and the second set of samples is the Landsat images composed with Band 4 (near-infrared) and Band5 (middle-infrared).

The subject of this study is to determine and to classify the polluted area resulting from a coal fired power plant in marine environment of the west Black Sea Region using one of the remote sensing methods: Landsat-7 ETM+ satellite imagery.

3. EXPERIMENTAL STUDIES

3.1. Chemical Analysis of the Solid Waste and the Coal Used in the Power Plant

Çatalağzı power plant (ÇATES) as unit B was built to produce electricity using pulverized bituminous coal, extracted in the region, in 1991. The power plant consist of two separate unit equipped with electrostatic filters to control air pollution rising from combustion. It uses 1,500,000 ton hard coal in a year. Coal specifications are given in Table 1 indicating low calorific value and high ash contents. The plant produces 645,000 ton/year slag and fly ash (mainly slag). Approximately 10 % of fly-ashes are sold to utilize in cement industry. Although there are electrostatic filters, unfortunately there is no any plant to control ashes. The ashes are collected from filters and burners and mixed with marine water in a 1/10 ratio, and discharge directly into the marine environment using 1105 meter long small size canals as seen in Fig.1 (Çates, 1998). Chemical analysis of slag and fly-ashes are given in Table 2, indicating main chemical components in the slag and fly-ash are SiO_2, Al_2O_3 and Fe_2O_3.

3.2. Sedimentation Test of the Solid Waste (Slag and Fly-ash)

In order to determine size distribution, sieving experiment of slag and fly-ashes was performed in the laboratory. It was found that 93 % of the sieved materials were less than 250 µm. The particles less than 100 µm in size were found to be 73 %. Sedimentation test were performed using (slag + fly-ash)/marine water mixture (the ratio was 1/10) as a function of the time to investigate settling and floating behavior of the particles. Sedimentation experiment reached in equilibrium in 5 minutes, and it was found that two separate region formed in the settling column. In order to calculate total suspended solid (TSS), samples were taken from test tube and TSS concentration were investigated as a function of time and settling velocity of the particles were found as 6.5 cm/minute.

In a previous study, it was found that further dilution of mixture with sea water did not affect the settling velocity and 99 % (w/w) of floating materials size dimension were between 175-416 µm. These results conclude that floating materials on the sea were from slag rather than fly-ash. It was also found that 3.5 % (w/w) of fly-ash and 20 % (w/w) of slag floated on the sea water in separate experiments using fly-ash alone and slag alone on the settling column. (Yetiş, and Arıcan, 1997). Experimentally 6 % (w/w) of the mixture (fly-ash + slag/sea water) found to be floating material from discharging.

Slag and fly-ash mixed with marine water are discharged into the marine environment causing pollution in the region. From discharge point, the pollution was spread out along the coast about 25 to 30 km and from coast through the sea about 8 to 10 km by wind and waves. Real case floating material is shown in Fig. 2.

Humidity % (w/w)	12.1
Flying matter % (w/w)	16.5
Carbon content % (w/w)	28.4
Ash ratio % (w/w)	43.0
Heat value (Kcal/kg)	3390

Table 1: Chemical analysis of the coal used in the power plant (Çates, 98).

Components	Slag (w/w, %)	Fly-Ash (w/w, %)
P_2O_5	0.11	0.18
SiO_2	59.58	57.45
Fe_2O_3	9.53	6.00
Al_2O_3	19.05	23.68
TiO_2	1.25	1.33
MgO	1.94	0.95
CaO	2.71	5.32
SO_3	1.30	0.22
Na_2O	0.75	1.66
K_2O	0.85	0.78
Heating Lost	1.43	0.65
Others	1.50	1.73

Table 2: Chemical analysis of slag and fly-ash (Türker, 2003; Bayat, 1998).

Fig. 1: Small size canals for transportation of the mixture and the waste discharging point.

Fig. 2: The floating materials on the marine environment.

4. REMOTE SENSING

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. Here the device is a remote sensing sensor that is operated from airborne and spaceborne platforms to assist in inventorying, mapping and monitoring earth resources (Lillesand, 2001).

Remote sensing sensor acquires data of various earth surface features that emit and reflect electromagnetic energy, and the data is analyzed to provide information about the resources under investigation. Electromagnetic energy is the energy source for remote sensing. There are many forms of electromagnetic energy such as visible light, radio waves, heat, ultraviolet rays and X-rays. These electromagnetic energies radiate in accordance with basic wave theory which can be described as $c = \nu * \lambda$ in which c is the constant means the velocity of light; ν is the frequency of the wave and λ is the wavelength of the wave, and both of them can be used to categorize the wave. In remote sensing, the electromagnetic wave is commonly described by their wavelength location in the electromagnetic spectrum (Fig. 3).

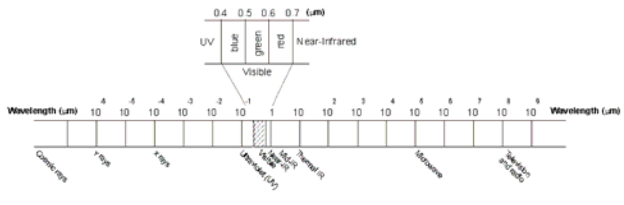

Fig. 3: Electromagnetic Spectrum.

Remote sensing sensor systems can record information of earth objects from such portions of the electromagnetic spectrum as the visible, infrared, microwave, etc. Many earth surface features manifest very distinctive spectral reflectance and emittance characteristics, and spectral reflectance curves can show this (see Fig. 4.). Earth surface features should have separable spectral response patterns if they need to be separated spectrally in remote sensing.

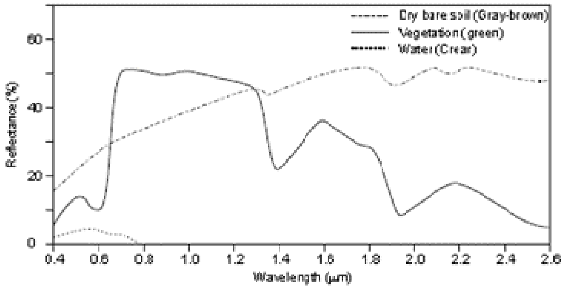

Fig. 4: Typical spectral reflectance curves for vegetation soil and water (Lillesand, 2001).

5. IMAGE CLASSIFICATION

The basic assumption for image classification is a specific part of the feature space corresponds to a specific class. Once the classes have been defined in the feature space, each image pixel can be compared to these classes and assigned to the corresponding class. Classes to be distinguished in an image classification need to have different spectral characteristics. This can be analyzed by comparing spectral reflectance curves. But if classes do not have distinct clusters in the feature space, image classification can only give results to a certain level of reliability. The principle of image classification is that a pixel is assigned to a class based on its feature vector, by comparing it to predefined clusters in the feature space. Doing so for all image pixels results in a classified image (Janssen, 2001).

Usually classifying means assign a number of objects to a certain class according to the class's description. Thereby, a class description is a description of the typical properties or conditions the desired classes have. The objects then become assigned (classified) according to whether they have or have not met these properties/conditions. In terms of database language one can say the feature space is segmented into distinct regions which lead to a many-to-one relationship between the objects and the classes. As a result each object belongs to one definite class or to no class.(Baatz, 2000).

5.1. Object Oriented Image Analysis

The most evident difference between pixel based image analysis and object oriented image analysis is that first, in object oriented image analysis, the basic processing units are image objects or segments, not single pixels. Second, the classifiers in object oriented image analysis are soft classifiers that are based on fuzzy logic. Soft classifier use membership to express an object's assignment to a class. The membership value usually lies between 1.0 and 0.0, where 1.0 expresses a complete assignment to a class and 0.0 expresses absolutely improbability. The degree of membership depends on the degree to which the objects fulfill the class-describing conditions. One advantage of these soft classifiers lies in their possibility to express uncertainties about the classes' descriptions.

The basic processing units in object oriented image analysis are objects or pixel clusters, with object oriented approach to analyze images; the first step is always to form the processing units by image segmentation. After introducing the basic fuzzy theory on which object oriented image analysis is based, the classifiers used in object oriented image analysis will be described in detail below.

5.2. Multi Scale Image Segmentation

The basic processing units of object-oriented image analysis are segments (also called image objects) and not single pixels (Benz et al 2004). The purpose of image segmentation is to first subdivide an image into groups of pixels (segments) corresponding to meaningful objects in the field. These objects are then classified. The size of the image objects is closely related to the scale of the analysis. The splitting/merging process is controlled by similarity or dissimilarity measures, relying on one or several image features, e.g. brightness or color, texture, shape, or size. The software used in this research, eCognition V4.0.6, is the first commercial classification package fully based on object-oriented techniques.

The choice of the segmentation parameters (scale, color, smoothness and compactness) was determined using a systematic trial/error approach, validated by visual inspection of the quality of the image objects. Once an appropriate scale was identified both the color and shape criterion were modified to refine the shape of the image objects. Two key scales were identified. A small scale (22) was appropriate to identify small vegetation patches in residential areas (e.g. private gardens, tree groups), and a larger scale (40) was good to extract larger vegetation patches (e.g. plantation, forest, pasture). Most published works found that more meaningful objects were extracted with a higher weight for the color criterion (Laliberte et al 2004). The color criterion was assigned a weight of 0.7, whereas the shape received the remaining weight of 0.3.

6. SATELLITE IMAGE DATA

6.1. Landsat 7 ETM+

Launched in April 1999, the Landsat 7 satellite included the Enhanced Thematic Mapper Plus sensor as its remote sensing instrument. The ETM+ sensor is also a high-spatial resolution (30 meter GSD) passive remote sensing system with 7 multispectral bands spanning the visible through IR spectral regions and an additional panchromatic band for a total of 8 bands (see Table 4). In addition to the advancements in radiometric stability inherent to the ETM+ sensor system the Landsat 7 vehicle records its position and velocity at the time of imagery acquisition, yielding a very accurate model of the vehicle ephemeris. (Charles M. S. et al., 2004).

Date	Satellite	Spectral Resolution (µm)	Spatial Resolution (meters)
04.07.2000	Landsat ETM+	0.45-0.52 Blue 0.52-0.60 Green 0.63-0.69 Red 0.76-0.90 Near IR 1.55-1.75 Mid IR 2.08-2.35 Mid IR	30

Table 4: Radiometric characteristics of the utilized datasets.

Landsat-7 ETM+ satellite imagery, dated 04.07.2000, was processed to find out a power plant solid waste effect on the surrounding environment, dispersion in the sea and possible impact on sea life. General satellite view of the region is shown in Fig. 5 representing industrial pollution dispersion in the marine environment.

Fig. 5: Landsat 7 ETM+ (3,2,1 bands) image of CATES.

Multi space image segmentation of the region is shown in Fig. 6. In this figure, marine environment is segmented into several parts including polluted area. Segmentation parameters were determined using trial/error approach. Segmentation parameters are shown in Table 5 as scale parameters: 40, color: 0.8, shape: 0.2, compactness: 0.5 and smoothness: 0.5. In this process, polluted area is segmented into three regions according to segmentation parameters.

Further classification of the polluted area was represented in Fig. 7. In this figure, industrial pollution resulted from power plant was classified into three regions: highly polluted area (first region, as number 1), moderately polluted area (second region, as number 2) and less polluted area (third region, as number 3). Their dimensions of polluted areas are calculated as 3.47, 4.01 and 30.25 km^2 that is shown in Table 6. High polluted area has the lowest dimension among the three regions whereas less polluted area has the highest dimension.

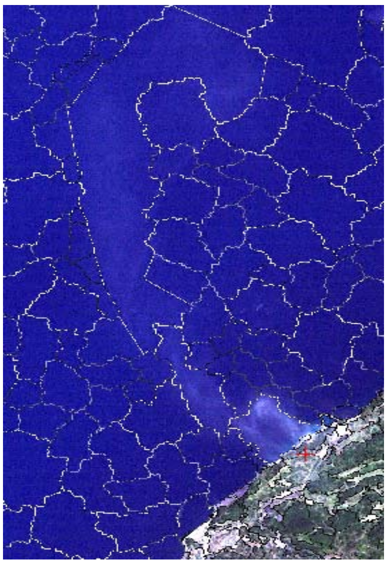

Fig. 6: Result of image segmentation.

Image	Scale Parameter	Color	Shape	Compactness	Smoothness
Landsat ETM+	40	0.8	0.2	0.5	0.5

Table 5: Segmentation parameters for segmentation and image classification.

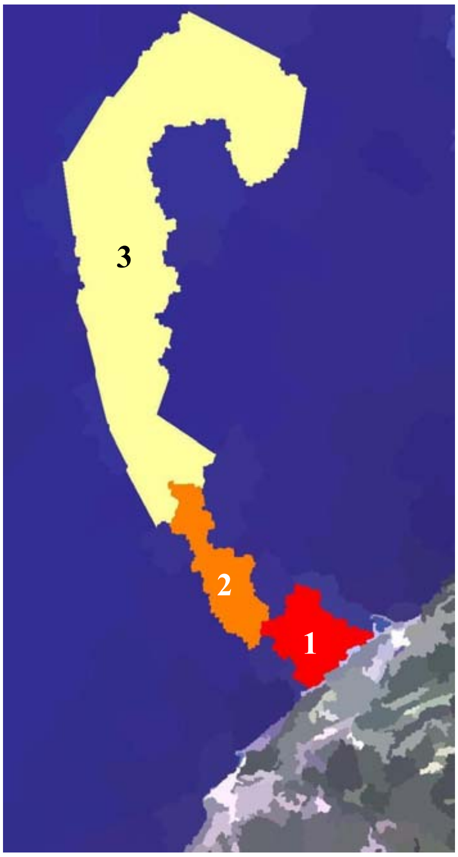

Fig. 7: Results of image classification.

Classes	Area (km^2)	Area (%)
1. class (red)	3.47	9.20
2. class (orange)	4.01	10.60
3. class (yellow)	30.25	80.20

Table 6: Classification of polluted area and their dimensions.

Pollution in the marine environment has affected the tourism all along the coast especially in the summer term. It also affects the planktons, sea plants, fish to breathe naturally and causing light shortening in the water. Therefore preventing dissolved oxygen concentration in the water environment. These problems result for breakage of food chain in the water ecosystem. In order to overcome this pollution, slag and fly-ash storage was decided to build near the area by local authorities. However, the fly-ash-slag storage dam is still under the construction in the region and is needed to finish soon.

7. CONCLUSIONS

Uncontrolled slag and fly-ash waste from the power plant has potential hazards in Zonguldak province and in throughout the west Black Sea Region. This study shows that remote sensing methods are not only used in land applications but also in marine environment application. Using remote sensing, one can observe and track pollution itself, its route, dimension and effects in the marine environment. The polluted area can be easily classified into three regions (first class as number 1, second class as number 2 and third class as number 3) having dimensions as 9.20% (most polluted), 10.60% (moderate polluted) and 80.20% (less polluted) respectively.

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