Identification of Damaged Areas Due to the 1999 Kocaeli Earthquake Using Satellite Remote Sensing

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1. Introduction: Information from remote sensing satellites has been used in various applications. Recently this technology has become a tool in damage identification after the occurrence of natural disasters like floods or earthquakes (e.g. Matsuoka and Yamazaki, 1999). The identification of damage from a large area gives vital information, which authorities can use to plan rescue procedures as well as to draw a general idea of the magnitude of the damage. The location of different types of damage, like fire outbreak, ground settlement and building collapse using remote sensing data is considered in this study. This analysis is conducted by comparing the satellite remote sensing images before and after the 199 Kocaeli Earthquake. A qualitative and quantitative identification is carried out using the improved images and the rationing of modified digital numbers.

2. Data: On August 17^{th}, 1999 at 03:01:37 a.m. (local time) an earthquake of magnitude Mw 7.4 struck the North Anatolian Fault Zone with the epicenter near the Gölcük city in the western part of Turkey. The data used in this investigation are remote sensing images from Landsat Thematic Mapper (TM) taken over the affected area. The images were taken on March 27, 1998, before the earthquake and on October 18, 1999, one day after the event. The images cover an area of 185kmx153km, as shown in the **Fig.1**. The characteristics of the Landsat platform are shown in **Table 1**. Before making the comparison, image matching was carried out. In this case, the ground control points (GCP) were determined using image-to-image technique. The GCP's were defined along main streets, coastal line and well-defined structures. From the whole image a Region Of Interest (ROI) of 1943 pixels x 769 lines was selected from both the pre- and post-event images. In this case the final error of the geographic correction was: $X_{axis} = \dfrac{2\,pixels}{(3906-1964)\,pixels} = 0.10\%$, $Y_{axis} = \dfrac{1line}{(1794-1026)lines} = 0.13\%$.

Table 1: Characteristic of Landsat/TM images.

Band	Wavelength (Micrometers)	Resolution (Meters)
Band 1	0.45-0.52 (blue)	30
Band 2	0.52-0.60 (green)	30
Band 3	0.63-0.69 (Red)	30
Band 4	0.76-0.90 (near infrared)	30
Band 5	1.55-1.75 (mid infrared)	30
Band 6	0.40-12.50 (far infrared)	120
Band 7	2.08-2.35 (mid infrared)	30

Fig. 1: Turkey and the area taken by the satellite images.

3. Area Affected by fire: In order to locate the areas affected by fire we make the comparison of the profiles. The profile represents the distribution of the digital number (DN) along of a strip of the image. This strip can be taken over the X-axis or Y-axis. For this comparison the Band 6 (far infrared or thermal band) is used. Since the images were taken in different seasons, the correction for the seasonal effect is made. This correction was made by subtracting the average difference between the digital numbers of images (pre and post-event) from the values of the digital number of the post-event image.

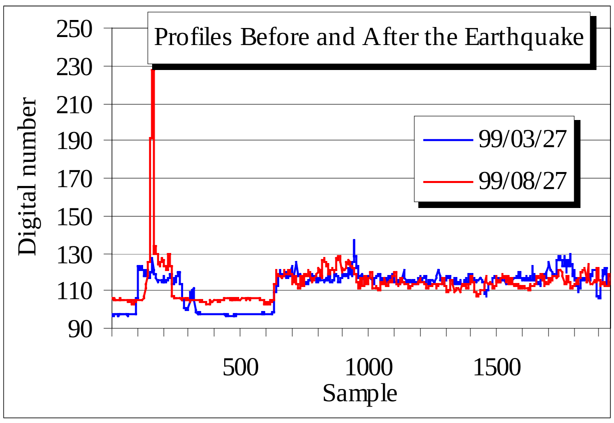
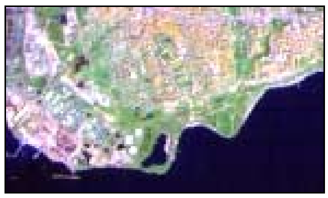
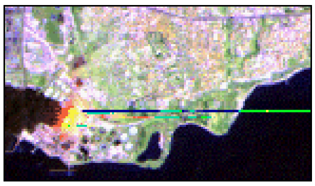


Fig.2: Corrected DN profiles before and after the earthquake.



(a) 1999-03-27 (before the earthquake)



(b) 1999-08-18 (after the earthquake)

Fig. 3: Image around the Tüpras refinery.

Key words: Damage identification, The 1999 Kocaeli Earthquake, Satellite remote sensing, Landsat, Ground subsidence.
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We can see in the **Fig. 2** that there is a pattern in the profile before the earthquake as well as in the after one. But in the region between Sample 100 and Sample 300 (this section corresponds to the refinery), there is a peak value that identifies the high temperature due to the fire in the refinery. The flat pattern sections in this graph represent the area of the sea.

4. Damaged Urban Areas and Ground Settlement: This study has focused the damage within the Gölcük city since it includes collapse buildings as well as areas sunk into the Sea of Marmara. This analysis was carried out by rationing bands. The band ratios are quotients between measurements of reflectance in separate portion of the spectrum. Ratios are effective in enhancing or revealing information when there is an inverse relationship between two spectral responses to the same physical phenomena (Campbell, 1996). If two spectral responses have the same spectral behaviour, the ratios provide little additional information. But if they have quite different spectral responses, the ratio between two values provides a single value that concisely expresses the contrast between the reflectance from the two images. In this study two kind of ratios have been studied the Infrared/Red ratio and the Normalized Difference Vegetation Index (NDVI). The NDVI is defined as: $NDVI = \dfrac{IR - R}{IR + R}$. Since our data comes from Landsat/TM optical image the IR and R bands correspond to Band 4 and Band 3, respectively. As a result of the arithmetic operations between images, we obtain two enhanced or improved images that correspond to image before and after the earthquake. These images contain NDVI, shown in **Fig. 4** and **Fig 5**.

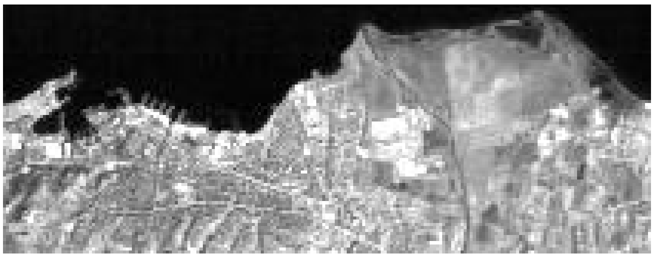

Fig. 4: Image before the earthquake enhanced by NDVI.

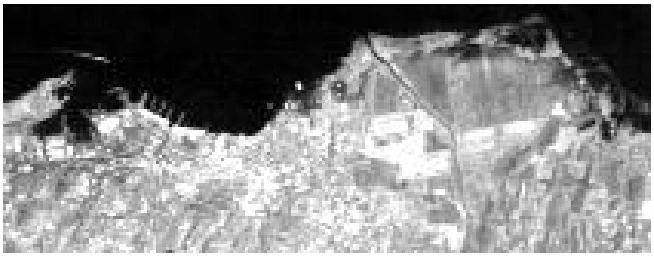

Fig. 5: Image after the earthquake enhanced by NDVI.

It can be observed in the upper-right part of these images there is a big difference. This difference is due to ground settlement. In the vicinity of east of Gölcük, the vertical offset was about 2m. The ground in the north of the fault settled down. This ground settlement and lateral ground flows in soft soils caused extensive and permanent flooding of large areas along the coast. The inundated area in the post-event image can be recognized because the reflectance in this region of the spectrum is very low and it differs from the one in the pre-event image. Also it can be distinguished in the centre of the post-event image a bright area that highly differs from the one in the pre-event image. This area contains damaged buildings at different levels, from total collapse to slightly damaged. The ratio of the average of the NDVI corresponding to different levels of damaged gives a quantitative analysis of these regions. This rationing, shown in **Fig. 6**, shows a trend from higher values to lower ones, it means from high to lower reflectance, except for the sunken zones, where the trend is reverse. The brightness in these areas is due to the spread of concrete debris after the building collapse. These results agree with the survey reconnaissance made by Architecture Institute of Japan, shown in the **Fig. 7**.

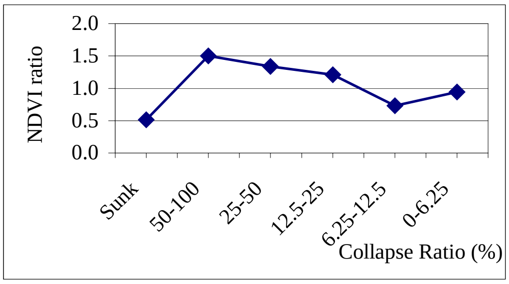

Fig. 6: Ratio of the NDVI After/Before.

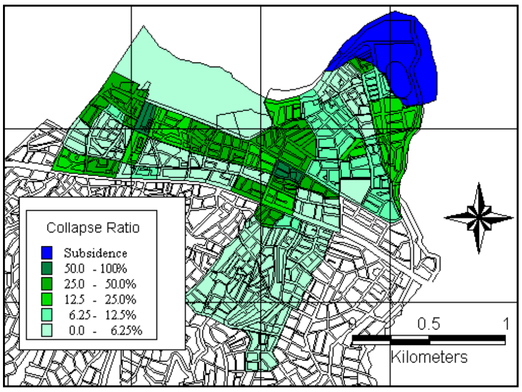

Fig. 7: Distribution of the damage in Gölcük (AIJ, 1999).

5. Conclusions: Landsat images before and after the 1999 Kocaeli Earthquake were investigated. The normalized difference vegetation index, NDVI, from the two images showed the difference in ground surface. After the rationing of the NDVIs, the sunken areas give smaller values while damaged urban areas give higher values, due to the increase of the reflectance. Although the results are in good agreement with the field survey, a further study using other bands and data from other areas is recommended.

6. References:

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