ENVIRONMENTAL IMPACT ASSESSMENT OF SURFACE GOLD MINING ON LAND COVER: A CASE STUDY OF CUKURALAN, IZMIR, TURKEY

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Abstract - Mining is an extraction of valuable minerals or other geological materials from the Earth, which involves the removal of vegetation, soil, and rocks. Mining itself, along with infrastructure associated with mining, such as roads and mining camps, results in several environmental impacts such as deforestation. Environmental consequences due to Land Use/Land Cover changes (LULC) can be monitored and determined efficiently using remote sensing techniques. The objective of this paper is to analyse LULC changes especially in the forest and mining areas by using Landsat TM and OLI data through years 1989 to 2017. In this context, supervised classification method and different spectral indices such as Normalized Difference Vegetation Index (NDVI) were applied to both Landsat 5 (2009-2010) and Landsat 8 (2017) image datasets to demonstrate the total changes during the mine construction. Finally, the LULC changes were evaluated by comparison of the output thematic maps produced using change detection methods.

Keywords - Remote sensing, Gold mining site, Multi-temporal Landsat data, Change detection.

I. INTRODUCTION

Mines are the main source of raw materials and minerals, e.g., metals, salt, and coal, for industrial and domestic usage; however, mining may affect the quality of the environment negatively [1]. It causes the destruction of natural ecosystems through a removal of soil and vegetation and burial beneath waste disposal sites [2]. Mining involves several stages; namely, site development, mining, mineral extraction, and mine closure. Each of these stages of the mining process has the potential for different impacts of various degrees depending on the sensitivity of local terrain, the type of technology employed, the skill and knowledge of the company and its ability to monitor and enforce compliance with environmental regulations [3]. Surface mining interrupts ecosystem service flows and results in inevitable and often permanent farmland loss and forest degradation. On the other hand, when rain, washes the loosened topsoil into streams, sediments pollute waterways. This can hurt fish and other plant life downstream, and cause disfiguration of river channels and streams, which leads to flooding. Likewise, dust pollution from heavy traffic on mining roads affects neighbouring communities and soil erosion are among common problems around mines [4]. Surface gold mining has become increasingly attractive during the last decades both in industrialized countries and in developing nations. Turkey actually has some of the oldest mines in the world and most of the gold found in Turkey is in the Western part of the country, especially in the Biga Peninsula, due to its geology. Since Turkey is located at an area of stress between tectonic plates (i.e. specifically, the African plate is being over-ridden by the Eurasian plate), prolific volcanism gave rise to a host of epithermal gold deposits in that areas. On the other hand, since the government regards mining as a strategic investment, the mining sector is supported with the greatest incentives, regardless of where the investment is located. However, this situation leads to an increase in the number of mining activities in Turkey. Although mining is an important component of the economy of many nations, particularly in the developing ones, mining causes widespread and drastic environmental and social effects on land cover. Also in Turkey, surface mining leads to widespread land transformations and forest degradation, which needs to monitor and quantify changes in vegetation cover. Furthermore, understanding and monitoring the environmental impact processes in mining areas is crucial for sustainable management of Earth's environment.Today, space-borne remote sensing technology having capability for repetitive multispectral sensing of large areas at low cost, is a powerful tool for the environmental impact assessment prior to mining, monitoring the areal extent and change in area of different activities during mining, and the evaluation of restoration success and landscape quality after mining [5].

II. STUDY AREA

Dikili is a coastal town and district of Izmir Province in the Aegean region of Turkey. The center town of Dikili is situated about 120 km north of Izmir. Çukuralan, a village of Dikili, is situated on the western slopes of the mountainous area (Fig 1). It is located in the coordinates of 39.1858° North latitudes and 26.9402° East longitudes. Dikili covers an area of

approximately 541 km^2 and altitudes ranging from 1 to 200 m above sea level. The area has a typical Mediterranean climate with mild rainy winters and hot dry summers. Means annual precipitation is about 686 mm most of which occurs in winter months [6]. his area is also famous for pine nuts. The world's finest pine nuts are produced in this region. However, the gold mining activities threaten these regions.



Fig 1. The map and satellite image of the study area.

The gold surface mining area is also shown in detail using Google Earth (Fig 2).

To better understand the social and the environmental impacts of surface gold mining, interview with farmers and stakeholders of Cukuralan village were also taken into consideration. Based on the official sources and interviews, the mine construction started in 2010 and thousands of trees have been cut and forest ecosystem was destroyed. Dust emissions from transporting trees damaged to the peanut pines.



Fig 2. Google Earth image of gold mining area.

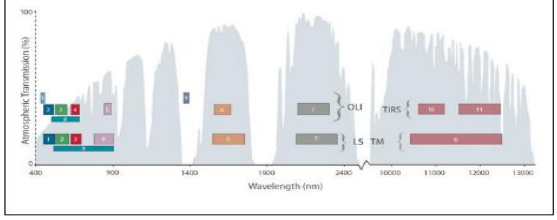
III. DATA

A. Satellite Data

In this study, the Landsat 5 TM and Landsat 8 OLI satellite images with 30 m resolution were used (Table 1). The time series of Landsat images were acquired from the USGS Landsat archive. The cloudless datasets belonging to the approximately same season were selected to avoid the seasonal changes as much as possible.

Table 1. Specifications of the satellite data used.

Satellite	Data
Landsat 5	1989-08-20
	2009-08-28
	2010-08-30
Landsat 8	2017-06-30



IV. METHODS

A. Pre-Processing

As a first step, the pre-processing technique (radiometric and geometric correction) was applied to Landsat images. Radiometric correction was not considered necessary, since cloudless image data sets were used for post-classification change detection analysis. As a geometric correction, images were rectified to a Universal Transverse Mercator (UTM) coordinate system, using World Geodetic System (WGS) 1984 datum, assigned to north UTM zone 35. Registration was performed to all dataset (1989, 2009, 2010, 2017) with ± 0.46, 0.37, 0.48, 0.40 root-mean-square (RMS) respectively. As a resampling method, the Nearest Neighbour resampling algorithm was chosen not to alter the value of the original input pixels. Then in order to extract the study area, spatial subset was conducted to all images.

B. Spectral Indices

To indicate relative abundance of features of interest, spectral indices which are combinations of surface reflectance at two or more spectral bands are widely used in image processing [7]. Normalized Difference Vegetation Index (NDVI), the most often used vegetation index, is an indicator of the greenness of the biomes. In this study, NDVI was applied for all multi-temporal dataset to distinguish vegetation from other Land Use / Land Cover (LULC) classes and see the changes in vegetation class (Fig 3 and Fig 4).

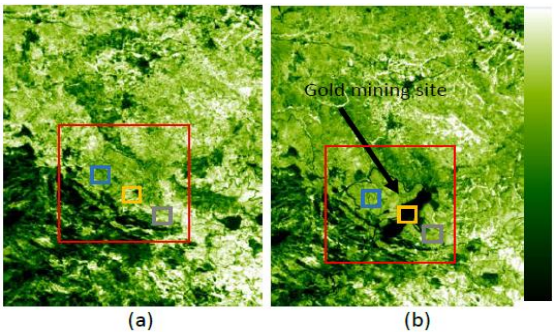


Fig 3. NDVI images of study area (shown with the red rectangle). (a) The date 2009-08-27 (b) The date 30-06-2017.

As shown in Figure 3, the amount of vegetation cover at the mine construction site has decreased (i.e. dark coloured area indicates the lower NDVI values) between 2009 and 2017. For a better interpretation of the NDVI images produced in the study area, two main classes (i.e. "Forest" and "Mine construction area") were taken into consideration and temporal NDVI value changes in three different sites named as "Region of Interest (ROI)" in the mining area (i.e. ROI 1, ROI 2 and ROI 3 which are shown in the Fig 4 as blue, orange and gray squares, respectively) were evaluated (Fig 4).

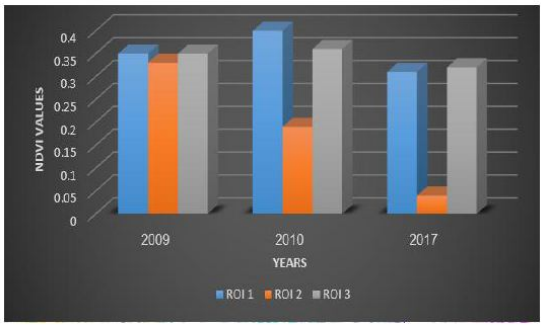


Fig 4. Changes of vegetation amount (NDVI values) in three different ROIs.

Additionally, as shown in Fig 5, the spectral profile of NDVI values was created by selecting a transect (profile) in the study area for better interpretation of NDVI changes. It is obvious that the NDVI values has decreased in 2010 and 2017 in comparison with NDVI values in 2009.

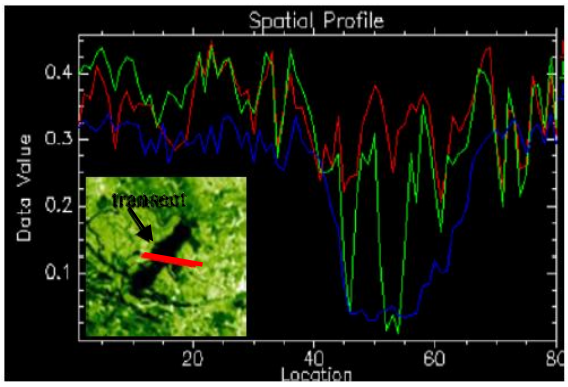


Fig 5. Spectral profile of the mining area obtained from 2009, 2010 and 2017 NDVI images.

C. Classification

For performing the land use/cover classification, supervised classification method was used. To this end, homogenously located sampling areas that best represent the objects on the image were determined via ROI tool. ROI's separabilities were evaluated and after selection of suitable bands, classification process was done using Maximum Likelihood method (ML). Maximum Likelihood algorithm is one of the most popular supervised classification methods used in remote sensing image analysis. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions [8]. Classification was applied to all multi temporal Landsat images (Fig 6). The six classes, (Forest 1, Forest 2, Bare soil 1, Bare soil 2, Mine construction area and Urban area) were taken into consideration.

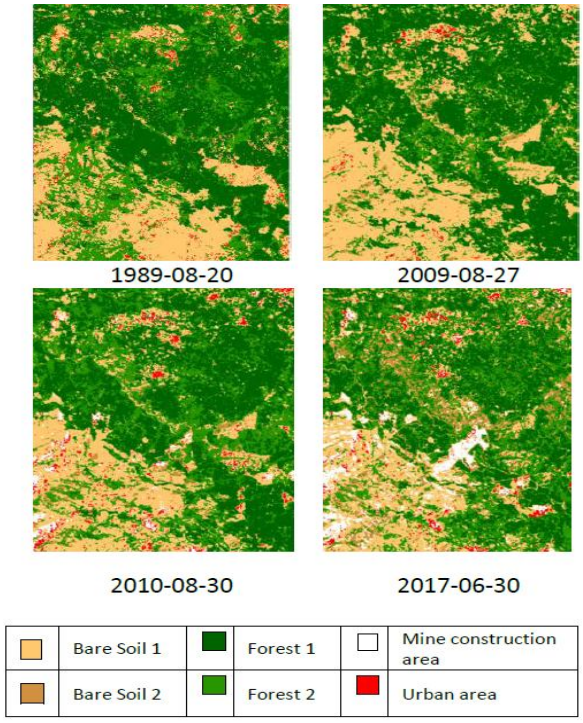


Fig 6. LULC maps of Landsat 5 and 8 datasets.

The accuracy of classified images was evaluated by comparing the classified LULC maps with reference maps and Google Earth images from 1989 to 2017 of the study area obtained from Google Earth platform. The user and producer accuracies were also calculated through a confusion matrix. The overall accuracy and Kappa coefficient of all dataset classifications are given in Table 2.

Table 2. The accuracy assessment result of the Landsat 5 and Landsat 8 classifications.

Satellite	Acquisition date	Overall accuracy (%)	Kappa coefficient
Landsat 5 TM	20-08-1989	96.62	0.94
	27-08-2009	95.89	0.93
	30-08-2010	95.43	0.93
Landsat 8 OLI	30-06-2017	93.46	0.91

As it can be seen from Table 2, accuracies were above 90% for all dates, indicating that each category was successfully classified. After accuracy assessment, the temporal and spatial variations of different LULC changes as a result of mining activities were evaluated. Among six different classes, two main classes namely "Forest1" and "Mine construction area" were selected and the amount of areal extent of the changes was analyzed. The land cover categories delineated in the study area revealed the changes in land cover statistics in (m^2) that have taken place during the period between 1989 - 2017. The result of the analysis is graphically represented in Fig 7.

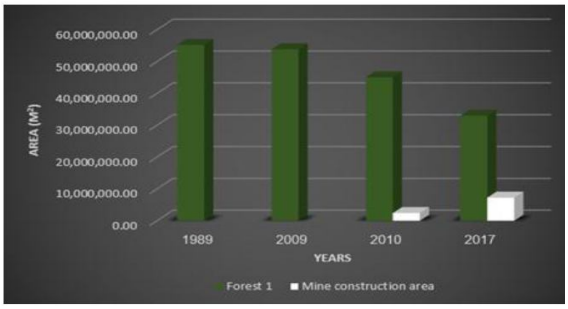


Fig 7. The multitemporal changes occured in the two main classes.

Results from Fig 7 indicate that the areal extent of the forest was 5522.67 ha and 5388.21 ha in 1989 and 2009 respectively. In 2010 the area covered by forest has decreased by 1015.74 ha in comparison with 1989 when mining construction started. In 2017, areal extent of the forest decreases to 3301,74 ha and mining area increased up to 726.12 ha which implies that mining operation was active during this period. Results show a comparative great loss in the forest area for the period of 28 years. The main change observed has been due to the clearing of forest areas for the mining purposes, which have resulted in significant decrease in the vegetation cover.

D. Change Detection

To monitor changes due to mine construction and its effects, change detection analysis was performed and post classification comparison method was used to evaluate "from-to" change information [9]. Change detection results are given in Fig 8.

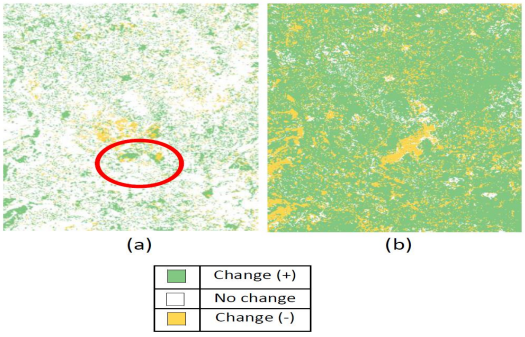


Fig 8. Change detection results. (a) In 2009-2010. (b) In 2010-2017.

As shown in Fig. 8, for the 2009 - 2010 time period (Landsat 5), the negative changes (shown with the red circle) in the forest areas nearby the construction site can be seen. This also proves the interviews (observations) which claim that the construction company had poisoned trees of the forest and cleared cut them in order to legalize the mining operation during this period (Fig 8 a).

2010 - 2017 time period (Landsat 5 & Landsat 8): Between 2010 and 2017, it was seen that the deforestation process was slightly continuing in the construction area since the mine construction has started in 2010.

CONCLUSION

Mine construction creates many environmental problems in which the chemical and physical properties of the spoil change to create a hostile environment [10]. In many countries of the world, mining activities are resulting in disastrous impacts on the basic life-support systems such as clean air and water, productive soil and the Earth's rich biotic diversity. This study focused on LULC changes in Cukuralan area characterized by the mining activities to ascertain the LULC changes. The multi-temporal Landsat 5 TM and Landsat 8 OLI satellite datasets covering the mining construction area were classified using MLC method. High classification accuracy (over 90%) was achieved for all dates. The comparative analysis from satellite images of 1989 - 2017 showed that area covered by forest has significantly reduced from 5522.67 ha to 3301.74 ha (40.21%) during this period while mining area has increased from 242.55 ha to 726.12ha (199%) during 2010-2017 period. According to change detection analysis done for the time period of 2009 – 2017, the main change was observed in the forest class. Deforestation due to mining-related land cover changes in the region was widespread, resulting in a loss of about 2220.93 ha. Our analyses of Landsat images showed that gold surface mining resulted in extensive land cover changes in the area, mainly leading to the loss of forests. As a result, there is an urgent need for mitigation measures to improve sustainable utilization of natural resources and to control negative mining impacts.

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