Evaluating the environmental impacts after the closure of mining activities, using Remote Sensing methods-The case study of Aliveri mine area.

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Abstract

The environmental impacts following the closure of mining activities are investigated in the area of Aliveri, located in Evia Island, Central East Greece. The mining works resulted in new and very complex hydrogeological and geomechanical conditions, that caused cracks and huge gaps in the surface. The remnant mining voids were filled with water, thus creating two lakes with important stability problems. These environmental data were analyzed and the observed changes were evaluated. All these changes were recorded using new techniques, such as Remote sensing methods (Landsat images) and GIS techniques. Ways for sustainable environmental management are suggested, in abandoned mines areas.

Keywords: Aliveri, open pit, underground mine, environmental impacts, remote sensing, mine water

Introduction

In Evia island, located in central-east Greece, near Aliveri town, there has been a lignite deposit of about $26,5x10^6$ tn (Figure 1). The surface of the study area is 110,32 km^2 and the average altitude about 264,5m. The exploitation started in 1951 using both, surface and underground mining techniques. The underground mining ended in 1980, while the surface activities continued until 1990. During the mining works, the dewatering procedure had to carry on, in order to keep the exploitation safe. The underground works developed in two different mines, Mine No 1 and Mine No 2. At the beginning, these two mines were not connected with each other, but later on, along with the progress of the works, they were connected through a number of tunnels (Minwater ECSC 2003).

In the wider area of Aliveri, the geological environment is consisted of limestones and loose neogene sediments. Above the neogene sediments lay the alluvial deposits (Figure 1). The mine waste deposits cover a wide area too (Dimitrakopoulos et.al. 2009).

Three aquifers are developed in the formations mentioned above :a)A lower karstic aquifer in the limestone, b)An upper aquifer in the overlying conglomerates, c)A confined aquifer is developed in the mine waste dump.

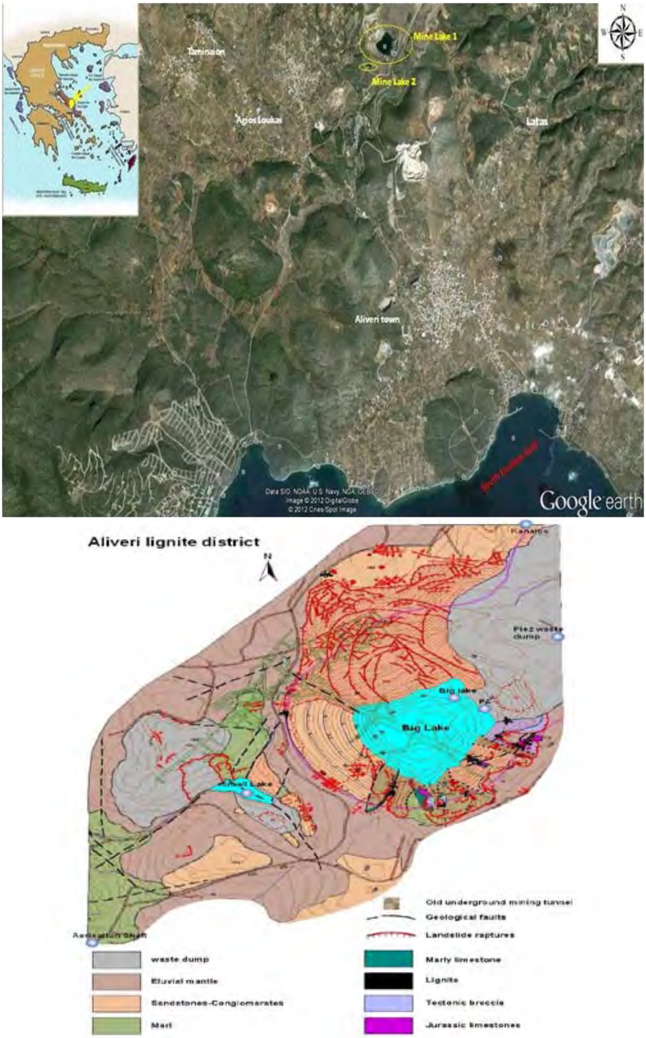


Figure 1 *The wide area of Aliveri (left), the geological map of the lignite district of Aliveri (right)*

Apart from the underground water systems, two surface water bodies ("Big Lake and Small Lake") were developed in the residual voids of the surface exploitation. The ponds are recharged through the surface run-offs (Figure 2, 3). The mining works (underground and surface) created new and very complex hydrogeological and geomechanical conditions, which resulted in the appearance of cracks and huge gaps in the surface. These cracks, voids and gaps have formed new flow patterns to the ground water. The aquifers have been connected in some areas and seawater – which was isolated by a clay layer – has now inrushed into the underground works. In the final voids of the open pit mine, small lakes have been formed. The lake was created after the completion of the surface lignite exploitation. In 1985 the level of the lake was at +35 m and in October 2002 at +60 m. The creation of remnant lakes seems to be an aesthetically acceptable solution, but it is not certain that this is also an ecologically stable one. Finally, failures of large extension appeared at the North Slope, which is not accessible (Figure 3) (Dimitrakopoulos et.al. 2009).

Figure 2 *The ``lake`` in Aliveri area*

Figure 3 *Southwestern slope of the lake, where failures were observed in the Neogene rocks (on the left).The western area of the lake (on the right), where subsidence depicted*

Concerning the water quality, during a research project from PPC (Minwater 2003), several samples (ground and surface water) were analysed in order to evaluate their hydrochemical composition. Concentration of Cl^- (192, 4 mg/l), based on Revelle index, indicates an influence to the aquifer by seawater. This is an indication that the aquifer is in hydraulic connection with the sea, but also with the underground mining galleries. The karstic water is of bad quality for drinking. The dissolution of limestones developing in the area, degrade the water quality and increase the salinity. The saline water approaches the limits of the mine (3 km distance from the sea). The water from the aquifer of the neogene sediments is potable and of a very good quality, (Dimitrakopoulos 2009). The significant difference of the water quality, in these two aquifers, indicates that they are different systems with minor or no hydraulic connection between them. The aquifer in the waste dump has generally high concentrations of SO_4^{-2}, Mn and Ni. These ions were possibly originated from the ash that was deposited at the waste dump of the old mines (Waterchem 2007). The water of the lake is generally of relatively good quality (Waterchem 2007). The shafts are filled with water and they need continuous pumping 150-200 m^3/h, in order to remain vacant and become visitable. This water can be used for irrigation, as it is not saline-water according to the chemical analysis (Minwater 2003-Waterchem 2007).

Methods

Remote sensing data, combined and calibrated with other types of datasets (derived from maps, measurement networks and sampling points), can provide information on surface water and land cover changes through a wide period of time. The overlapping and processing of these different data collecting techniques synthesize an essential and very important environmental monitoring tool for mining areas. Synergistic use of remote sensing, field, laboratory and bibliographical data can create a GIS database, useful for storing, processing and retrieving environmental data (Charou 2010 and Toren 2001). The dataset used in this study includes, topographic and hydrogeological maps, Landsat TM, Aster of various acquisition dates, hydrogeological and land-use data. GIS programs were used for the environmental data analysis and the evaluation of changes.

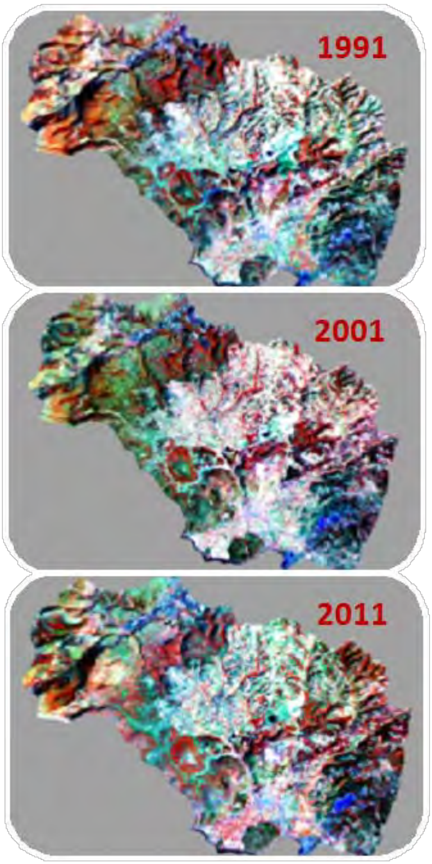
The area of the lake was calculated based on thresholding the TVI images. The Transformed Vegetation Index (TVI), shows vegetation vigor computed from near-infrared and red spectral bands. The TVI formula takes the square root of the difference between the infrared and red values. If this difference is less than zero, the square root cannot be calculated for integer output. The raster image was converted to vector in order to capture the shore line and its changes through the years. (Unwanted polygons were manually excluded). An RGB combination (R:TM4, G:TM5, B:TM3) for all images is shown below (Figure 4).

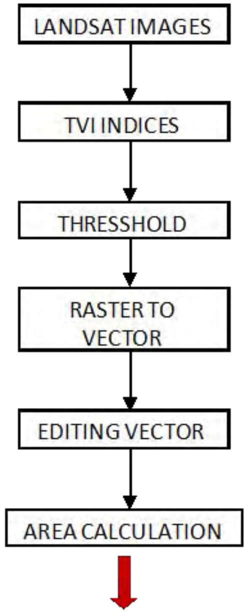
PPC (MinWater 2003) has measured a rise of the lake level in about 25 m, during the last 17 years, that indicates the changes of the water table of the aquifers. The water reservoir of the lake is estimated at 450.000 - 500.000 m^3, which is also the total capacity of the lake. The surface of the lake is increasing with time. The main recharge of the lake is rainfall, which is very high in the area, about 900 mm annualy. This was verified from the satellite images, that showed increase of the surface during the last 20 years.

As presented below (Figures 5,6) the Land Use of this area is mainly agricultural lands with vegetation, based on the Land Cover of Corine 2000. Farming covers a significant surface area and the mineral mining sites are very limited, which was expected as mining exploitation has finished. As described in the land use map, in the south east site of the basin there is quarrying activity.

NDVI (Normalized Difference Vegetation Index) is a commonly used Vegetation Index that indicates the amount of green vegetation present in the pixel. Higher

NDVI values indicate more green vegetation. NDVI for the Aliveri region and the years 1986, 1991, 2011 was calculated and clustered using a K-means clustering algorithm. For each year, four clusters were formed namely Very High, High, Low and Very Low NDVI values. The clustered NDVI values are presented (Figure 7) for Aliveri region for the years 1986, 1991, 2011. Although a direct comparison of the absolute NDVI values for these years is not possible, an increase of the percentage of Low and Very Low NDVI values (increase of abundance of Light Blue and Blue colors) is observed. This is an indication for the degradation of the vegetation which is in accordance to the land use /land cover changes interpretation (Figure 7).





Date	1991	2001	2011
Area(m²)	13.500	23.400	35.100

Figure 4 *An RGB combination (R:TM4, G:TM5, B:TM3) for all images*

Reduction of vegetation cover can be interpreted from 1986 to 2011 (green colors of Corine classification scheme). Also expansion of discontinuous urban fabric (red colors of Corine classification) scheme which is quite evident around Aliveri area (Figure 8). Finally land cover fragmentation can be interpreted from the images dated 1986, 1991 to 2011 which is evident by the numerous polygons assigned to different classes. This generalized classification cannot be used for the interpretation of the evolution of the of the open-pit mining activity during the 1986 to 2011 period. Accurate identification of training classes to various features of the surface mines have to be assigned like surface extraction areas, tailing pools, waste-rock piles, removed vegetation, reclamation areas etc.

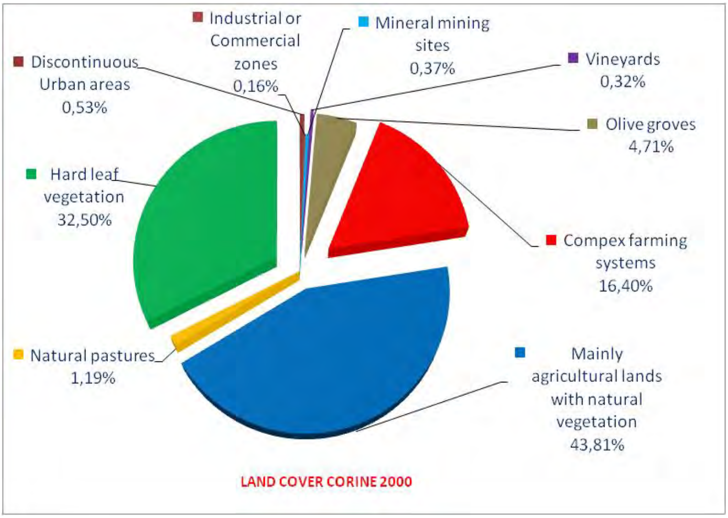


Figure 6 *Statistical diagram of land use classification*

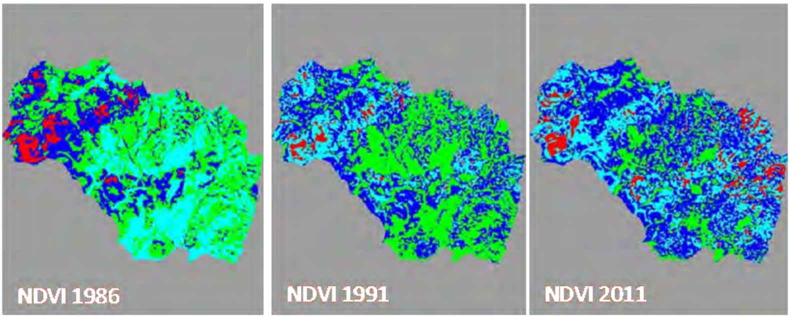


Figure 7 *NDVI clustered values (Red: Very High , Green High, Light blue: Low and Blue: Very Low)*

Figure 8 *Classification result of images according to Corine 2000 classification scheme. The same color scheme has been assigned as the one used for Corine land cover.*

PPC had compared two digital terrains elevation of the area, for the year 1985 and 2001 by using the photogrammetric compilation that was accomplished on four vertical planes more or less parallel to the four slopes of the mine (MinWater 2003). In the year 2001 from photogrammetric compilation, they distinguished in the center of the mine there is a lake. The absolute level of the water was 58.40 m. In 1985 a lake also existed at the bottom of the mine, but in lower elevation (MinWater 2003).

Results and Discussion

Remote sensing data should generally be linked or calibrated with other types of data, derived from mapping, measurement networks or sampling points, to determine the parameters, which are useful in the study of mining hazards. Satellite images offer multispectral approach, synoptic overview and repetitive coverage (Woldai 2001). Evaluating the remote sensing methods and the field data, in Aliveri area, the voids are demonstrated, that have created due to the underground mining. These activities caused extended faults and subsidence. There are changes in the Land use and in the surface of the Lake. The environmental impacts in the area are many, concerning the stability and water resources (Dimitrakopoulos 2009).

The phenomenon is in progress and is influenced by the following factors: a) The erosive water activity. The surface water which flows through the high permeable conglomerate and breccias, takes away their clay-sand material and results in the augmentation of the voids, b) The residual voids in the sub-surface workings in combination with the erosion. The underground voids have been filled up with water. The fluctuation of water table has caused the strength degradation of the formations and the pillar destruction that, subsequently, ends in the collapse of the galleries and indirectly, in the landslide of the slopes.

Conclusions

Mining operations cause degradation of the land, loss of forest, changes in topography and hydrologic conditions and pollution of useable surface and groundwater. After the closure of the lignite mines, the region was degraded environmentally.It is desirable to optimize and minimize environmental impacts by adopting proper mining techniques. The demand of the local authorities is the development of the surrounding area. The abandoned area could be used as playground, as conference center, parks, water-parks, spots fields, museum for the mining history in the area.

``New`` lands for irrigation have been created in the old waste dump areas. The management of the mine water of old mining shafts and galleries will improve the geotechnical conditions of the area (subsidence, failures etc). The quantities of water in the old mines and in the lake are capable to cover most of the needs of the area for irrigation, industrial and other uses. The rational exploitation of the existing water reservoirs (lake, water wells, galleries) will help to minimize the enviromental impacts and it will be a significant start point for the development of the area. The intensive and continuous pumping out of the old mining works is necessary to maintain the galleries secure and visitable for tourist exploitation. The enrichment the bad quality water by surface flows and the rainfall, it is possible, so the water could be proper for various uses. The proper management of water resources and environment will solve many of the environmetal problems in this old mining-abandoned area.

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