TRACING LANDSCAPE CHANGES NEAR OPEN PIT MINES

Chief assistant Hristo Nikolov
Chief assistant PhD D. Borisova
Space Research and Technology Institute - BAS, **Bulgaria**

ABSTRACT
Open pit mining areas in Europe are responsible for 8333 km^2 according to Corine2006 data. In this paper we focus our research on the change of landscape in the one of the most exploited mining regions of Bulgaria – Panagyurishte ore region. We investigate the impact of the mining industry in this specific region since it is exploited starting in the early 60-ties of the last century. In our previous research we traced the changes of the environment at small scale investigating specific open pit mine and one of the conclusions was that an extensive study encompassing the whole region is needed. In this case we are focused on the developments taking place in larger area and the impact this specific type of activities has on the land cover/land use. We expect that the results from this study can be used for better planning at regional level. Main source of data used throughout this research are multichannel data from TM/ETM+/OLI instruments and this choice was based on the two essential for this study requirements – repeatability of the data and derived products and the open access to them. For verification of the results additional data from other sources were also used – in-situ measurements made by the team at specific points of interest, digital orthophotos, DEMs, etc.

Keywords: *open pit mines, landscape impact, mulchichannel data, Natura2000 sites*

INTRODUCTION

One of the most explored and exploited mining area is the ore region of Panagyurishte which is part of the metallogenic belt Apuseni-Banat-Timok-Srednogorie and where more than 150 ore deposits, ore occurrences and mineral indications have been established and documented [1]. The total area of the said region is about 600km^2 located in the central part of Bulgaria. On Fig. 1 shown are the directions of the main faults and thrusts and also the location of the main ore deposits under current or ceased exploitation providing mainly copper and molybdenum – namely Elatsite, Chelopech, Medet, Asarel, Elshitsa and Tsar Asen sites. The majorities of the mentioned deposits are or has been worked out by open pit mining causing serious changes in the landscape during the years. In our previous research we have studied some of the temporal transformations in the areas inside the open pit mines and the areas close to them used as temporary or permanent dump sites and even some tailing ponds constructed [2], [3], [4]. This was the reason we decided to investigate further the impact of these anthropogenic objects on the landscape with special focus on their influence on biologically sensitive areas present in Etropole and Panagyurishte municipalities. According to data from the national authorities responsible for the implementation of the Habitats (92/43/EEC) and Birds (79/409/EEC) Directives there are two types of monitored and reported locations – protected territories (currently in Bulgaria their number is 1015 covering 5,3% from the total area of the country grouped into 6 categories – reserves(55), national parks(3), landmarks (348), maintained reserves(35), natural parks(11), protected areas(563)) and protected zones (currently there are 340 zones covering 34,4% of the whole territory).

In order to mitigate the posed problem we processed multichannel data from one and the same instrument (namely Landsat based TM multispectral scanning radiometer [5]) for two years from 30 years period in order to evidence the landscape transformations. Results from this research are compared with the existing vector data from Natura2000 project for the protected sites and all CORINE projects for Bulgaria. In our study reported are findings related to the change of the areas covered by every specific object as pointed out previously. Other goal pursued was to check if some soil reclamation activities have been carried out at the sites of closed open pit mines such as Elshitsa and Tsar Asen as expected from the development rehabilitation plans at the regional inspectorate for environment and water.

The rest of the paper is organized in the sections as follows – first we provide short description of the anthropogenic objects having major impact on the landscape in the region studied, next shortly is outlined is the methodology we used, in third section presented are the results obtained from this research, in the forth one a discussion of the results is given, and finally conclusions are drawn.

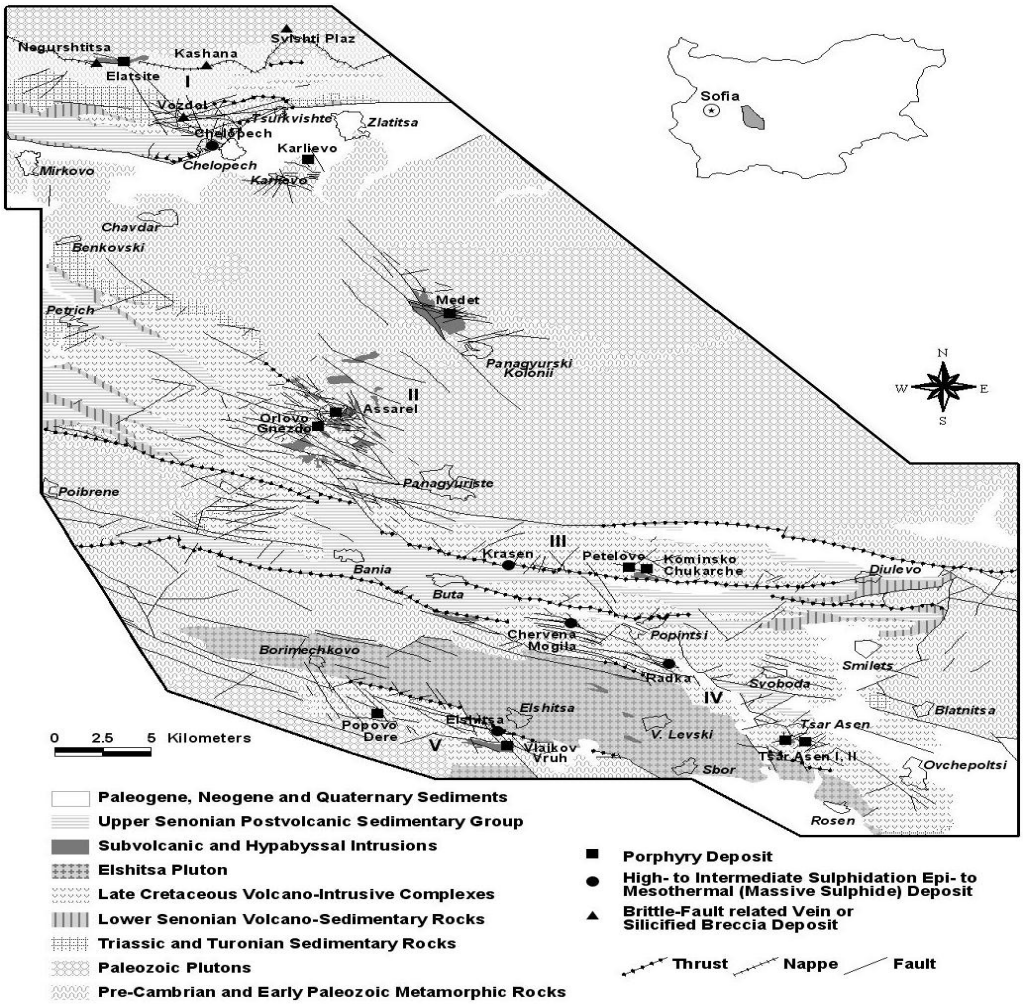


Fig. 1. Geological Map of Panagyurishte Ore Region (compilated by K. Popov) Ore Fields: I - Elatsite-Chelopech; II - Assarel-Medet; III - Krasen-Petelovo; IV - Radka; V - Elshitsa

REGION

In this study the region of interest is composed of several unconnected areas all related to open pit mining. Below we provide short information about two of the sites investigated since they are considered as main contributor of landscape change being fully operational mining complexes.

1. Asarel-Medet

The Medet mining complex, has been surveyed in the early 60s and started ore production in 1964 of the 20th century, at that time being the largest copper producing mine in Europe and third largest in the world at that time. Its full production capacity of 8 million tons of ore per year has been reached in 1972. In 1984 in compliance with the project the Medet Mining and Processing Complex started reducing ore mining and copper, pyrite and molybdenum concentrate production and it terminated its activity in the early 1994. The landscape close to the Medet mine throughout the years is presented in (Fig. 2 a-c).

The Assarel deposit is of copper porphyry type and has hydrothermal formation and is located some 12km away from the Medet deposit and started production of copper concentrate in late 1989. The main ore minerals found in it are chalcosine, pyrite, chalcopyrite, bornite and coveline, as the average copper grade is 0,45%. Annually the mining complex comprising open pit mine, main and auxiliary dump sites, a tailings pond, and ore flotation plant processes 10–13mln tons of ore delivering copper concentrate and cathode copper. In its infrastructure this largest Bulgarian mining company

Medet 1970 Medet 1980 Medet 1995

Fig. 2. Pictures of the landscape of the surroundings of Medet open pit mine

besides main facilities for open pit mining and copper ore processing also operates a return water sector, copper microbiological leaching facility, cyclic flow conveyor technology for mined material transportation, SX-EW facility, purification stations, etc. Also stations for monitoring of water conditions in two of the rivers flowing in the region have been set and their data are provided via the website of the company maintaining the site (see Fig. **3)** [6].

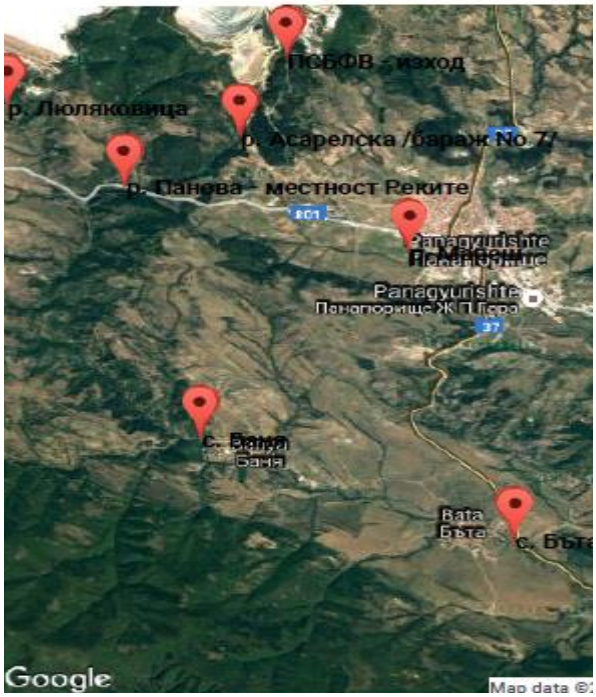


Fig. 3. Places for water condition monitoring close to Asarel site

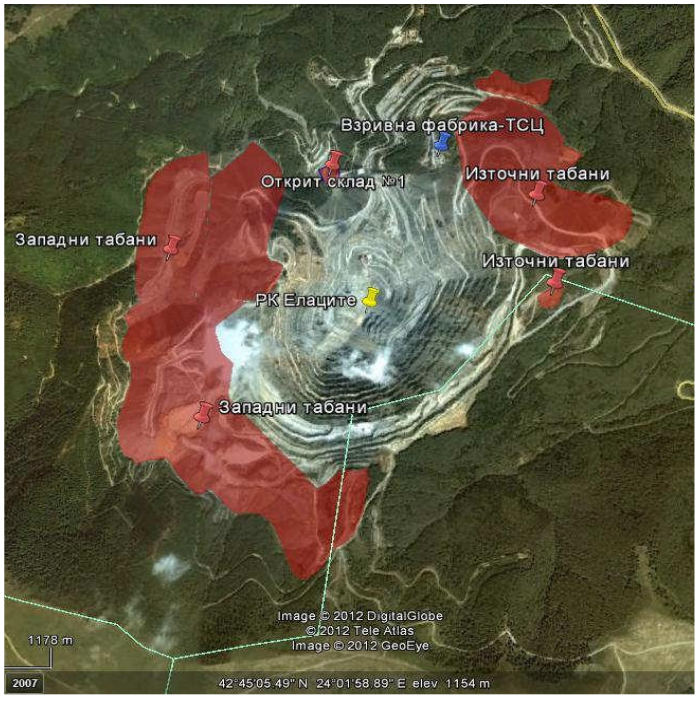


Fig. 4. Schematic view of the Elatsite open pit mine and its dump sites [7]

2. Elacite

"Elatsite-Med" mining complex operated by the company with same name has two sites – an open pit mine "Elatsite" and a ore processing complex near village Mirkovo. The open pit mine is located on a small mountain Baba (part of the Western Balkan Mountains, near Mount Baba) and its development throughout the years has led to a change of the relief at the local level. It comprises the mine and two closely situated internal dump sites (see Fig. 4). The extraction of ore began as early as 1983 and the mine is scheduled for operation by 2022 since there are still 65 million tons ore to be extracted. The total quantity of rock material extracted in 2014 was about 51 million tons with some 20% of it being overburden. The mining activities certainly affect the microclimate of the area since by removing natural mountain barriers and the decrease in the altitude of the area of the mine conceded the smooth passage of the winds. Other influence from the mining works is the water pollution this why in 2014 a modern water treatment plant has been constructed in order to improve the quality of the water inflowed into river Malak Iskar.

The ore processing complex consists of flotation plant and two tailing ponds for the waste material from the flotation process. The plant started production in 1981 using the tailing pond Benkovski-1, but after 1992 it become obvious that more area is needed so tailing Benkovski-2 (maximum project area 396,5ha) has been created (see Fig. **7**). Since the wind is primary transporter of dust pollution from tailings ponds adjacent to settlements his regime is of great importance to the environmental situation in its vicinity. This is the reason why the areas of the both tailings are closely monitored by the site operator and more specifically checked at regular basis is the area of the water table which should decrease the spread of dust from them.

Data

This study is mainly based on freely accessible raster and vector data concerning the past and modern state of the sites investigated. Multichannel raster data originate from TM instrument [5] path183 rows 30&31, dates Nov 14th 1986 and Sept 13th 2010. Since the region we needed for this research falls within the overlapping area between two scenes as observed by the satellite this was the reason both pairs of scenes were first merged. Next processing step was to extract a part from the merged scene using previously created vector layer which includes all sites of interest.

With regard to the vector layers used for this research they were collected from several sources, but mainly from the Executive Environment Agency since this administration has the duty to collect, process and distribute data for the ecological state of Bulgaria. Parts of this data are the vector layers concerning protected areas and biodiversity obtained as result from several projects such as Natura2000 and CORINE [8] and were used for validation of the results from processing the multichanel ones.

RESULTS

First result we obtained was from processing the vector data from all the CORINE projects for Bulgaria in order to check the transformation of the sites investigated and created was a table with their areas (see Table 1).

Table 1. Areas of the sited studied as reported by CORINE projects

	Year			
	1990	*2000*	*2006*	*2012*
	Area of the site [ha]			
open pit mine Asarel	420,69	447,72	447,69	14362,69

tailing pond Lyuliakovitsa	251,44	263,42	263,38	415,96
Asarel dump	–	114,87	166,49	254,34
open pit mine Medet	301,86	303,20	303,20	303,17
Medet dump	64,91	71,24	71,24	71,21
open pit mine Elatsite	495,50	514,87	541,13	554,17
tailing pond Medet	354,54	358,19	358,17	358,17
tailing pond Benkovski-1	264,55	271,11	271,13	275,46
tailing pond Benkovski-2	–	191,54	214,61	386,73
Elshitsa dump	45,86	45,86	45,84	45,81
Elshitsa waste	127,57	125,31	125,29	125,27
open pit mine Elshitsa	152,24	152,17	152,18	127,94
open pit mine Tsar Asen	70,11	60,98	61,02	69,25

As we expected the areas corresponding to developing sites such as Asarel show steady increase, but for the sites related to no operational ones such as Elshitsa and Tsar Asen the areas occupied remain the same for the period. It is worth to comment the case of Elatsite since in the period considered it shows small change of the area used (the increase is of some dozens of hectares) which is the behavior of no operational mining site, but the fact is that the mine has been developed in depth and the increase of the total area is only due to expansion of the dump areas (see the red areas in Fig. 4). This result shown for Elatsite site matches with the area of the concession agreement as given to the operator of the open mine.

Fig. 5 confirms the construction and development of the Asarel site. On the left displayed is the state of open pit in 1986 confirmed by the yellow line from CORINE1990 and visible is the absence of the dump on the north side and the tailing pond Lyuliakovitsa in south. On the right side of the same figure exhibited is the situation as in 2010 which confirm the relatively small increase of the open pit mine area and the creation and enlargement of the tailing pond and the dump site.

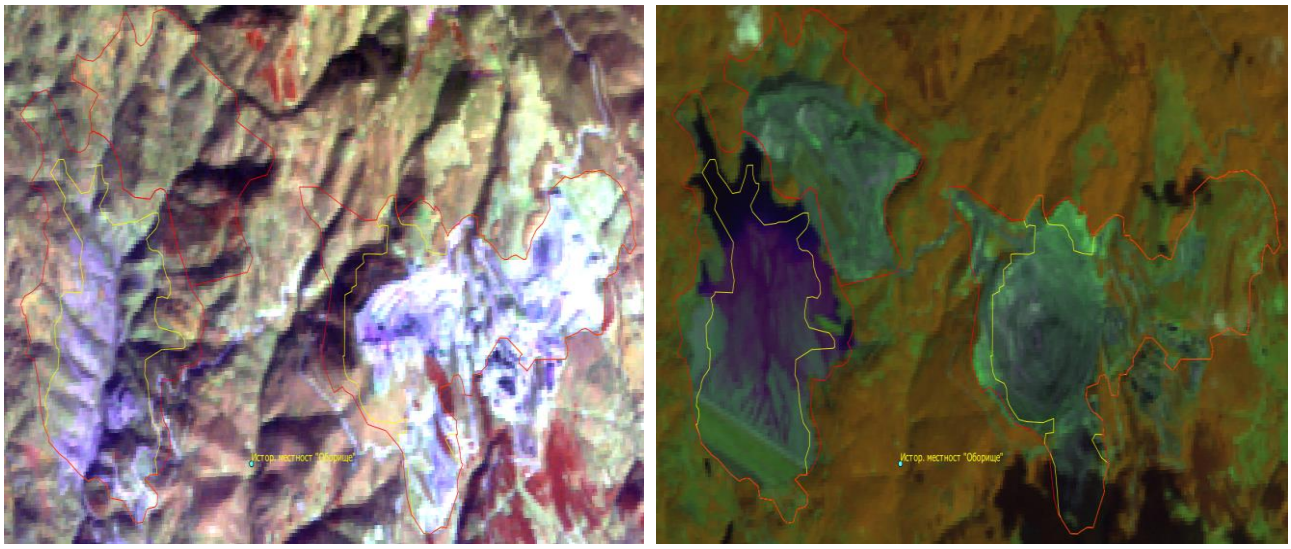


Fig. 5. Vector layers for CLC_1990 (yellow) and 2012 (red)

As seen in the **Fig. 6** below no further development of the Tsar Asen site is evidenced by multichannel data processed. On the right part of the figure it can be seen the increase of the areas covered by vegetation (reddish pixels) over the former dump site of the open pit mine. Also from the same data it can be attested that inside the pit of the mine water has started to accumulate.

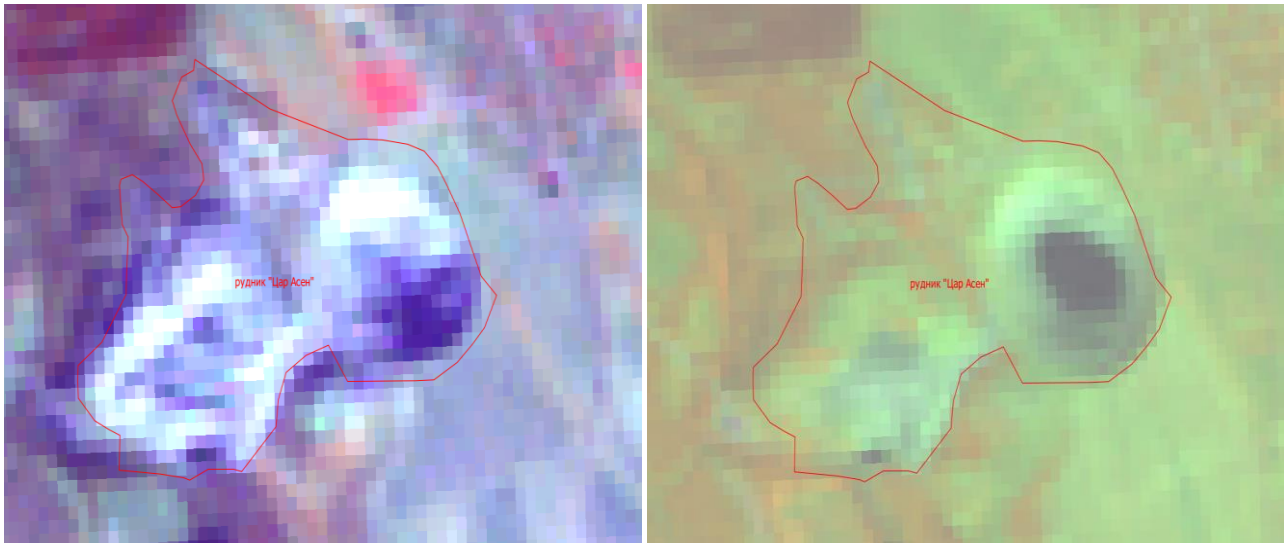


Fig. 6. Raster images for years 1986&2010 of the no operational site Tsar Asen

On Fig. **7** we present results evidencing the soil rehabilitation activities in one of the tailing ponds close to Mirkovo for the two years we investigated. Even from visual inspection of both images it is noticeable that only small part of the pond *Benkovski-1* (in the upper part) is still used for deposition of flotation tailings while the newly established one *Benkovski-2* (not visible in 1986) has developed throughout the time period concerned.

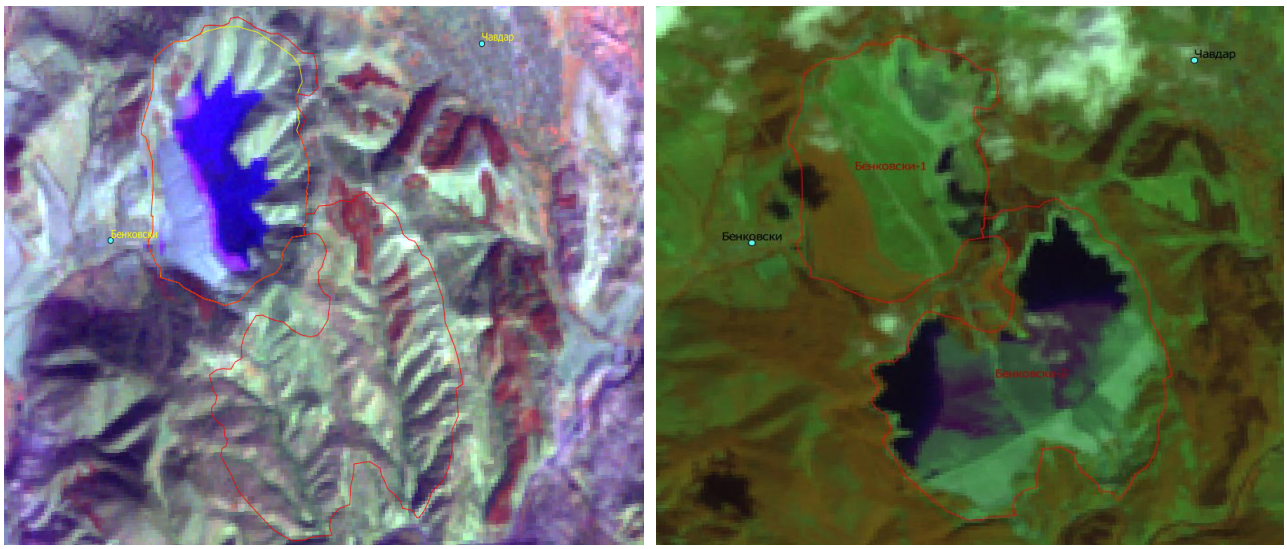


Fig. 7. Tailing ponds Benkovski-1&2 TM data from year 2010 overlayed with CORINE2006 vector layers

This result can be used in the next years as benchmark in order to monitor the spread of the last in the next years and is also proof that this tailing has not exceeded the projected limits since the data are from year five years after the vector file has been prepared.

Processing only vector layers from Natura2000 and CORINE projects a map has been created in order to assess the impact of the sites under consideration on the protected zones under Directives 92/43/EEC and 2009/147/EC (Fig. **8**). In the Table 2 summarized are the names of the zones being directly affected by the activities on those sites which complement the information from the map.

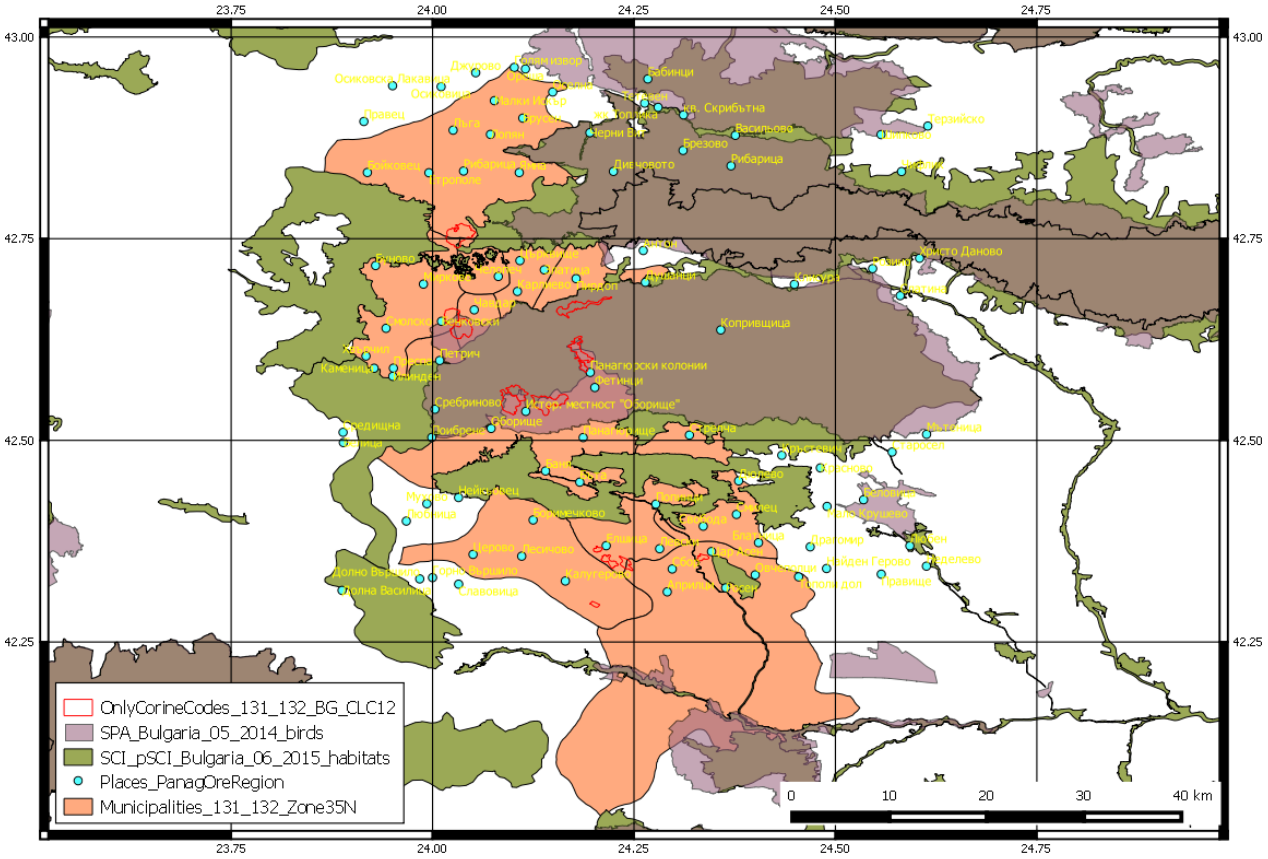
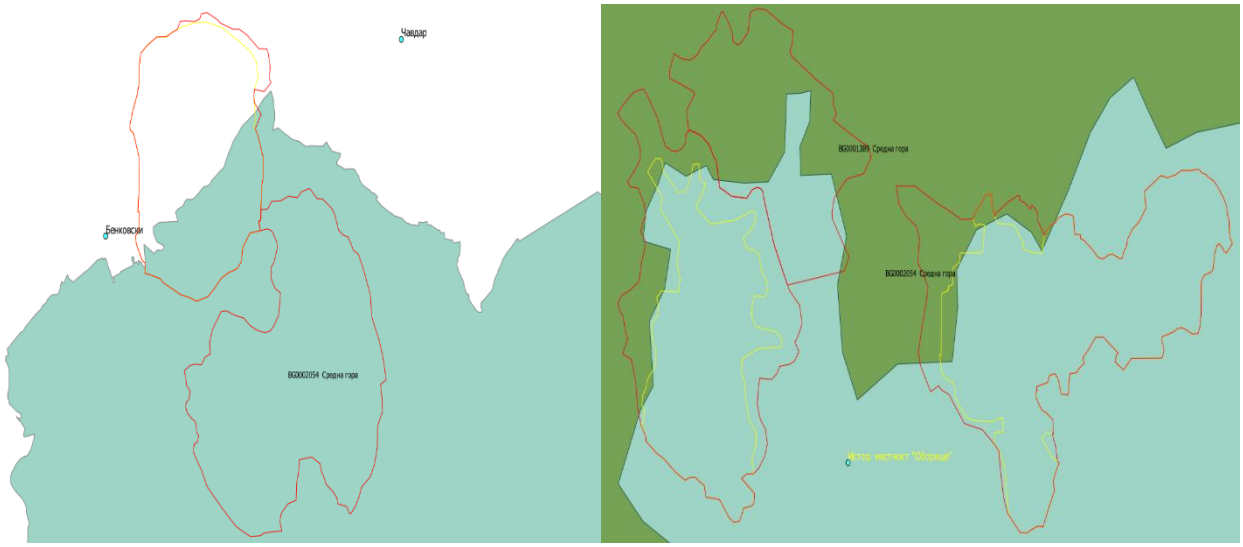


Fig. 8 Map of the sites investigated overlaying the zones under Directives 92/43/EEC and 2009/147/EC

Table 2. Protected areas being influenced by the activities at the sites studied

Mining related site	SPA – Directive 2009/147/EC	SCI – Directive 92/43/EEC
Elacite site	Tsentralen Balkan buffer Etropole-Baylovo	Tsentralen Balkan buffer
Benkovski-1&2 tailing ponds	Sredna gora	Sredna gora
Medet open pit mine	Sredna gora	Sredna gora
Asarel open pit mine	Sredna gora	Sredna gora Popintsi Reka Luda Yana
Elshitsa site	–	–
Tsar Asen site	–	Ovchi halmove Reka Luda Yana

On the figure Fig. 9 can be seen the impact on the Natura2000 protected areas by two of the investigated sites. While the Asarel site takes only peripheral parts of the zone which is under Directive 92/43/EEC (dark green), but both sites are completely inside a zone under the Directive 2009/147/EC (light blue).



a) b)

Fig. 9. Intersection of vector layers of the tailing ponds Benkovski1&2 (a) and Asarel site (b) with layers for Natura2000 protected sites

DISCUSSION

Using the results shown in the previous section it is to be mentioned that the in the region researched there are two working sites with open pit mining– Asarel and Elatsite both following the rules set in the national Environmental Protection Act [9], [7] and three no operational ones. Several are the transformations on the landscape caused by the active mining sites and evidenced by remote sensing – horizontal extension of the areas of the open pit mines and the dumps (Asarel); decrease of the height of some hills due to need to reach the working horizon for the deposit (Elatsite); creation of new or extension of existing tailing ponds (Benkovski-2); rehabilitation of dumps or tailings (Benkovski-1, Tsar Asen).

In this study it was demonstrated that for the examined active sites there is no unauthorized increase in the areas as proved by independent surveys such as CORINE projects. Since both active open pit mines are planned for production until 2030 there is no prove found that any rehabilitation measures have been taken already. Unfortunately the areas of the decommissioned sites keep occupying the same areas for the period addressed (see Table 2) so an assumption can be made that those are not subject to reclamation works up to now.

For the tailing ponds information based on remotely sensed multichannel data from regular observations can be used in estimation of the areas covered by water table. This is an important parameter for the ponds since the water prevents dust from the site to be spread by wind blows in the surrounding areas leading to soil contamination by heavy metals. For example at municipal level there are ready plans for rehabilitation of tailing pond Medet and a 1km buffer area around it, but the data processed hasn't proved a progress of this action.

With regard to the impact on the protected sites it was determined that the areas of the active mining do not violate the limits of the concession approved. As mentioned in [9] and [7] all anthropogenic activities are in regions developed by human works for long years so they are not natural habitats, but would be of interest if in the localities where the mining works have been discontinued for more than two decades some natural habitats have been restored.

CONCLUSIONS

In this study we made an attempt to investigate the impact of several mining sites from Panagyurishte ore region on the landscape based on information from freely accessible raster multichannel data and vector data. We proved that this information provides reliable results in detecting changes of land cover and can be used for regular monitoring of the development of the activities in the mines and adjacent areas. Other goal achieved in this study is that by combining results from two projects – CORINE and Natura2000 – new type of information can be provided to the public.

REFERENCES

[1] Popov P. et al., Main features in geology and metallogeny of the Panagyurishte ore region, Annual of MGU, vol. 46, part I, Geology and Geophysics, Sofia, 2003

[2] Borisova D., H. Nikolov, D. Petkov, B. Banushev, Multitemporal remote sensing data in open pit mine monitoring, Ecology workshop, pp. 27-34, Farago, 2014, ISBN 978-954-2961-75-8

[3] Borisova D., H. Nikolov, B. Banushev, Assessment of environmental conditions close to abandoned open mines, Proceedings of 7th Congress of the Balkan Geophysical Society, Tirana, Albania, 18650.pdf, ISBN 978-90-73834-55-2, 2013, doi:10.3997/2214-4609.20131724 http://www.earthdoc.org/publication/publicationdetails/?publication=71451

[4] Multitemporal satellite data in mine waste monitoring of Medet copper deposit. Borisova, D., H. Nikolov , D. Petkov, B. Banushev, International Conference "SPIE Europe Remote Sensing", Edinburgh, UK, 2012

[5] ESA 3rd party missions – https://earth.esa.int/web/sppa/mission-performance/esa-3rd-party-missions/landsat-1-7/tm-etm/sensor-description

[6] Officail site of Asarel-Medet JSC – http://www.asarel.com/Actual/Ecology.aspx

[7] Report on the environmental impact "Elatsite Med" 2013 – http://www.bd-dunav.org/uploads/content/files/upravlenie-na-vodite/PURB-2016-2021/Razdel-5/Podkrep_doc_R5/Podkrepyasht_5SWB4.pdf

[8] Anton Stoimenov, Radka Koleva, Ventzeslav Dimitrov, Youlin Tepeliev, Todor Lubenov, and Julia Kroumova, Satellite mapping of Bulgarian land cover – CORINE 2012 project, Forestry ideas, vol. 20, No 2 (48):189–196, 2014

[9] Investment plan "Increase of industrial areas of Asarel Medet JSC", 2009 (in Bulgarian)