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ОПРЕДЕЛЯНЕ НА СЪДЪРЖАНИЕТО НА ЖЕЛЯЗО В МИННИ РАЙОНИ ПО ДИСТАНЦИОННИ ДАННИ

Деница Борисова, Христо Николов, Мирослав Данов, Румяна Кънчева

ЦЛСЗВ – БАН София 1113, ул. Акад. Г. Бончев, бл. 3
E-mail: (dborisova, hristo)@stil.bas.bg;

ASSESSMENT OF IRON CONTENT IN MINING-IMPACTED AREAS BY REMOTELY SENSED DATA

Denitsa Borisova, Hristo Nikolov, Miroslav Danov, Rumiana Kancheva

Solar–Terrestrial Influences Laboratory – BAS
Bulgaria Sofia 1113, Acad. G. Bonchev St., bl. 3
E-mail: (dborisova, hristo)@stil.bas.bg

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Abstract *- The monitoring of the environmental impact of open mines and the improvement around mining areas is very important because of the long term contamination of large territories. Methodologies that can observe and model the amount of mine waste are very suitable for this purpose. Remotely sensed multispectral data obtained by Landsat TM in combination with ground based field and laboratory spectroscopy data were used to assess the ecological impact of iron ore mining activities in a densely populated region in Bulgaria. Mineral and rock samples were collected during a field campaign in the study area. Main parameters to be identified in detail include lithology and vegetation cover. All main lithologies were recognized by the spectral features of diagnostic minerals. Information for the iron content in the ore minerals were acquired through chemical analysis. A spectral decomposition approach was used to determine proportions of rocks and vegetation. The results of the remotely sensed data analysis (lithological and mineralogical components, iron content and vegetation cover) were included into a model for predicting the iron content in sparse vegetated areas. The present study was supported by NSFB under Contracts NZ-1410/04 and MUNZ-1502/05.*

INTRODUCTION

The exploitation of mineral resources is always associated with change of the land cover. Thorough monitoring of degraded areas is an essential task for effective management of surface mine recovery (Parks et al, 1987).

The methodology of widely used *change* detection, based on digital data, is the process related to the changes of the land-cover properties. By this means the changes in the land cover between two dates are highlighted. Change detection has been used in many applications such as land-use changes, rate of deforestation, urban areas alteration implementing remotely sensed data along with spatial and temporal analysis procedures and digital image processing techniques.

The geological exploration of the iron-bearing rocks in the Kremokovtsi region started in the late 50-ies of 20-th century. As a result the mining plant “Kremikovtsi” was built who started its production 1963. The main activity of this plant is extraction and recovery of iron together with all relevant engineering and commercial actions. The experience for exploration and mine plant construction gained on this site was implemented on other mine plants across Bulgaria during 60 and 70-ies of same century.

In both cases the ore deposits are developed by open pit mining and together with the dump areas are one of the largest pollutants of the environment in this region. That is the reason to start monitoring and rehabilitation activities for the whole region.

This policy for ecologically clean production could be supported to great extend by data obtained by new remote sensing instruments with their increased spatial resolution. Compared with the data taken 20 years ago the spatial precision of the data improved more then twice which may result in better decision support. This is the motivation of the team – to develop better understanding of the reclamation process and its monitoring. Two main types of land cover were considered during this study namely top soils and vegetation cover. The other natural phenomena subject to the negative influence of the mining activities, the water, was not examined since the hydrographic network has smaller spatial dimensions than the resolution of the instrumentation used to gather data and field measurements were not carried out.

MATERIALS AND METHODS

To estimate the impact of the mining activities on the environment as major indicator of the ecological state the areas covered by vegetation and the top soil chemical composition in the region under study was adopted. The main assumption in this case is that using spectral properties of main types of land cover their current state could be estimated with acceptable error (Mishev, 1985). Especially for the mentioned types this holds to be true since their spectral reflectance is quite dissimilar (Clark, 1999).

As a main indicator for the ecological state of the investigated areas the density or presence of the vegetation cover was chosen. The reasons for this decision were two – it can be reliably estimated by remotely sensed data and we obtained extensive knowledge, mainly from geographic and ordnance surveying sources, about the state of these areas before the exploitation had started.

The main source for airborne data for the spectral reflectance of the land cover was the freely available data sets from Landsat TM/ETM+ instrument (GLCF, 2005). The acquisition dates for both scenes are in first decade of June which guarantees equal illumination conditions and phenological state of the vegetation.

Since the region under study falls into edges of two adjacent scenes from different dates of year 1987 first a mosaic of them was made and a subset of this data was produced. After this procedure the geometric and radiometric properties were not distorted which resulted in correct data. From this dataset the two target areas (open mine and dumps) were extracted by their visual discrimination from the surroundings. The same procedure was applied on data from year 2000. This way the data necessary for change detection procedure were created.

The accuracy of the digital numbers comprising these data sets was verified comparing them with laboratory reference reflectance spectra of the similar types of land cover acquired in a field campaign. Even in case of mixed pixels (which is the case for pixels from the borders of the areas) implementing the methodology of the unmixing theory (Borisova, 2005) on the data the vegetation/soil proportion was determined easily thus increasing the precision in determining the areas covered by a specific end-member (mine, dump, vegetation). This approach was implemented in our research eliminating more than 15% of incorrectly taken pixels for dump sites and 8% for the mine region.

RESULTS AND DISCUSSION

The multispectral airborne data from TM/ETM+ instruments were used through this study. In fact they represent mixed pixels containing reflectance from at least two components - soils and Fe-bearing minerals embedded in sediment rocks. The spectral reflectance curves of the classes of interest, shown on Figure 1, are close to these ones obtained by other researchers after laboratory measurements (Clark, 1993). For this study we obtain our own samples from the open pit and from the dump. Laboratory measurements of ore minerals were performed with laboratory spectroradiometer. The instrument provides data in the spectral range 0,5 – 2,55 um with bandwidth less than 0.01 um. The statistic reliability is guaranteed by integrating 10 spectra per sample per measurement. The obtained spectral reflectance of the samples from the dump sites were compared with similar ones taken from spectral library (Clark, 2003)

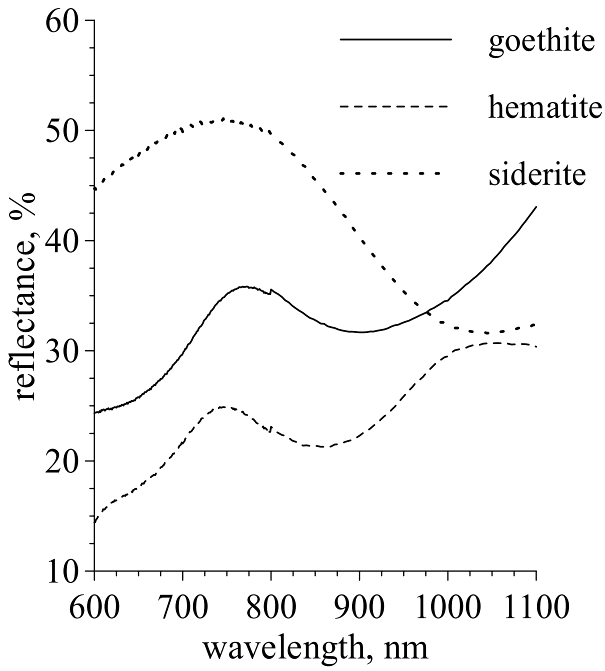

Figure 1. Spectral reflectance curves of the classes of interest

On the next step NDVI values for the pixels covering the areas of interest were calculated (Crippen, 1990). Based on them the edges of both regions were accordingly corrected once again.

	Open pit	Dump
1987	942 pixels	580 pixels
	847 800 area [m^2] *	522 000 area [m^2] *
2000	984 pixels	1070 pixels

	885 600 area [m^2] *	963 000 area [m^2] *
Change	37 800 area [m^2] *	441 000area [m^2] *
* the areas are calculated with spatial resolution 30m/pixel		

Table 1. Number of pixels and corresponding areas of RoI

In the table above, for both open pit and dumps, the number of pixels and the corresponding areas are given. The results for both areas are quite different since the main mining activities from year 1987 was turned to the deep exploration the deposits. The observed change in the landscape near the mine site is mostly due to expansion of the roads leading to the dumps.

Additional information for the dump sites is the chemical composition of the ore material. This in Kremikovtsi opencast mine contain the iron and this element is a potential pollutant in the region. The iron absorption at 0.8 um is reduced in depth according to it content. The 0.9-um-absorption line shifts position with elements substituted for iron (Clark, 1999). On Figure 2 the dependence of reflectance at 0.8 um on iron content in the studied samples of the embedding rocks is presented. With the increasing of the iron content the reflectance values at 0.8 um decrease as well. This dependence is based on content of widespread iron and is one possible approach for detection of a spatial distribution of iron content. Similar model of the dependency was used in the unmixing process mentioned above.

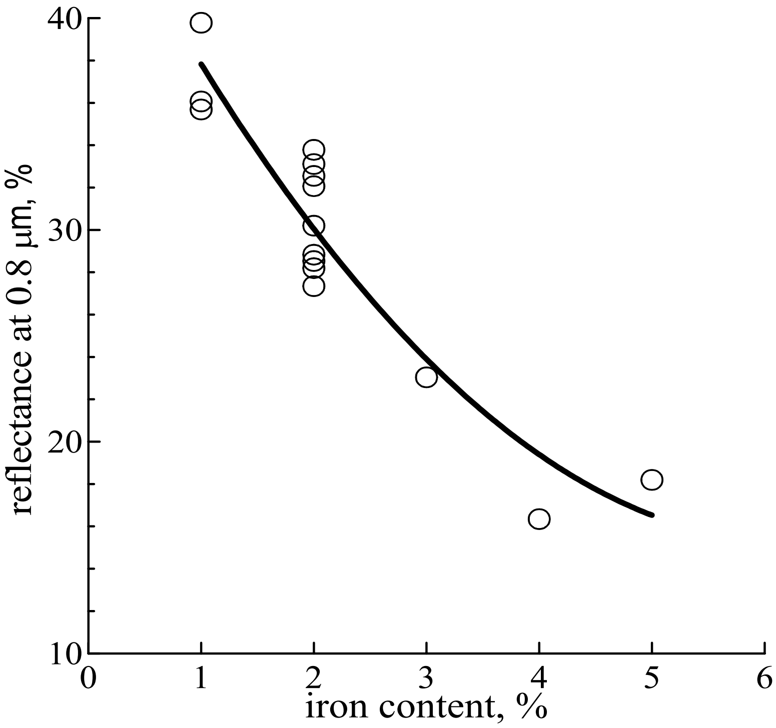

Figure 2. Dependence of reflectance at 0.8 um on iron content in the studied samples of the embedding rocks

CONCLUSIONS

In this paper a practical approach to establish correspondence between laboratory, field and airborne measurements for ore minerals has been discussed. The conclusion of this study is that a consistent and reliable methodology for estimation of the area of the regions of mines and dumps using remotely sensed data with relatively moderate spatial resolution. The above results prove that methodology for spectral decomposition technique is capable of estimating the end-member fractions quite accurately. The main advantage of the presented technique is that mixed pixels are used during the training phase. Compared to these other techniques, the present one is simple, cheap and objective.

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