ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE
OCHRONY ŚRODOWISKA
Rocznik Ochrona Środowiska
Tom 13. Rok 2011 ISSN 1506-218X 117-136

6

Cost-effective Land Mining Restoration Decision Making Using Geospatial Data and Multi-criteria Analysis

Nicos V. Spyropoulos
Agricultural University of Athens, Greece

1. Understanding the need of geospatial and multicriteria analysis in mining management

Satellite imagery provides a cost effective alternative to conventional field and aerial surveys for monitoring when, where and how much mining and reclamation efforts have been progressed [1]. Since the last five years, conventional remote sensing applications for natural resources exploration have been dominated by high-resolution Earth Orbiting systems such as IKONOS and QuickBird. High resolution imagery provides the detail necessary to indentify structures such conveyor belts, mining equipment, roads, dump sites etc. This enhanced imagery saved countless hours of field work in monitoring, verifying and planning almost all mining activities. A broad series of applications to enhance information available to mine managers uses various satellite data, from medium to high resolution. A recent demonstration of these applications reveals that a series of base maps can be formatted for direct input into mining company's existing GI system [2]. This combined information along with other data and reports, provide accurate up-to-date site specific information as often as every few days eliminating the need for manual information collection and digitization which can be exhausted and expensive work. The first information to be entered to a mine GI System is the base mapping that is helping identifying existing road network and adjacent exploration and dump sites. Land-cover and land-use information categorize the mining property into classes according to spectral and spatial characteristics of surface features (vegetation, bare soil, mixed areas etc.). This classification procedure will also help to identify reclaimed and unreclaimed land and restored dump site's vegetative growth vigour. The tonal variations based on spectral signatures, allows mining experts to extract plant health information on newly restored sites. This information can improve the regulatory environmental compliance and overall site integrity [3]. With just some points-and-clicks the disturbed landscape versus the undisturbed or restored can be calculated.

When it comes to environmental concerns which means at the end of the day the environmental compliance the "six million dollar question" is where to restore and what will be the new land-use type all in the context of the "minimum cost" [4].

Having all these plethora of spatial information and access to other information data sets such as meteorological data, soil erosion models, plantation and fertilizations costs, climate change data, the mining expert is looking for a straight forward methodology that will be able to feed in data from one side and get alterative restoration solutions from the other. The increasing mining production cost, the fierce competition and the environmental concern necessitates the development of a cost-effective methodology capable to provide less defensible and well balanced restoration alternatives. The present study is investigating the cost-effective use of geospatial data derived by medium and high resolution monosocopic, stereoscopic, panchromatic and multispectral satellite data at nickeliferous mining sites in Greece and compares decision support systems that are using two different multi criteria analysis methodologies: the Mutli-attribute Value or Utility Theory and the Outranking Approaches.

2. Sites and Data

The study experimental sites are the three nickeliferous mining sites of Larco’s mining company located at Pagontas, Sourtzi and Isoma in the Island of Evoia Greece. The mining operations started by late sixties generating and annual production of 17000 tonnes of Ni in the form of FeNi.

The climate is typical Mediterranean with mild winters and dry and warm summers. The annual mean precipitation is 700 mm. Natural vegetation is very rich with coniferous pine forests and fir trees. The relief is variform and the elevation of the experimental sites is ranging from 800 to 1300m.

Three multispectral Landsat TM images at 30 m of the path/row 183/33 were selected. The acquisition dates were 22 May 1986, 29 June 1991 and 18 April 1997. Additionally, one monospopic KVR-1000 image with two meter spatial resolution was acquired in May 1992 to help extract liner earth features inside the mining areas. One SPOT PAN stereoscopic pair, with 10m resolution and acquisition date of Jan/Feb 1993 was also used to provide the 3-D model. Two additional Google based QuickBird images were also used for verification purposes dated on 16-Aug-2002 and 5-Jul-2007 respectively.

3. Analysis

All satellite image data set was coregistered and georeferenced to the Hellenic Geodetic Reference System. The inputs to the land-cover and land-use classification were the corresponding six bands of all Landsat (except the thermal band 6) images. All applicable bands were corrected for atmospheric scattering effect with the dark object substation method. Six classes were generated and evaluated by visual interpretation of false colour image and each class subsequently was assigned a land-cover land-use type. The evaluation determined that from the Landsat TM images 6 classes could be separated (forests, artificial lakes, roads and benches, dump sites, shadows and bare rock [fig. 1]) whereas when you fused the Landsat data with 2 m KVR image [fig. 2] the classes can easily increased to 10 (including man made structures such as conveyer belt, factory equipment, various buildings collapsed dump sites, newly planted areas, position and width of exploitation benches).

For change detection mapping image ratioing/differencing, Principal Components Analysis and Post Classification comparison [fig 3] were used. SPOT stereoscopic image pair provided the DEM of the area with 10 m resolution. DEM derived information such as slope, aspect and hydrographic network was also produced.

Once the information content from geospatial data was set then the task was to identify a methodology to simulate the decision steps based on multicriteria analysis with the less defensible and well balanced restoration alternatives.

In the following decision support system (figure 4) phase E has been tested using two different multicriteria methods. In this phase all the processing of constraints, cases, strategies and scenarios were happened through a multi-criteria analysis, where strategies scored against predefined criteria.

The multicriteria analysis can be determined as a systematic and mathematical standardised effort of resolution of problems that results from refuted objectives. The satisfaction of these objectives cannot be complete [5]. The available choices in a such problem present the most excellent record only for one or more – but never for all – the objectives, because then would not exist the problem of decision: the choice that would satisfy a such treaty would be most excellent. It is therefore necessary a compromise between the refuted objectives. The person in charge for the decision-making should select one or many objectives, which he wishes to maximize, as well as the compensatory losses that he is willing to accept as for the remaining objectives. The significance of compromise which leads to the accommodating solution – in contradiction to the most excellent solution – declares the character of decisions – solutions that are sought in the multicriteria problems.

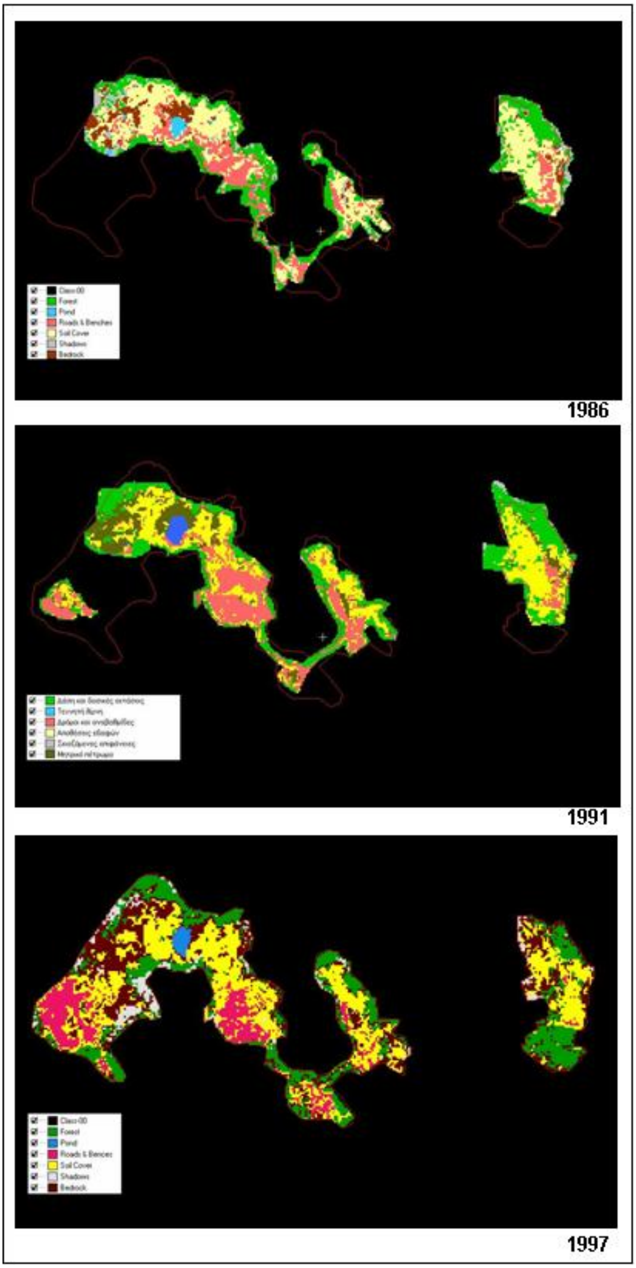

Fig. 1. Diachronic classification maps 1986, 1991 and 1996 over Pagontas mine
Rys. 1. Diachroniczne mapy klasyfikacyjne kopalni Pagontas w 1986, 1991 i 1996

Fig. 2. Monoscopic KVR scene highlighting the linear features of the mine such as roads inside the mines, position and width of exploitation benches, various buildings and other man-made objects etc. Pagontas mine
Rys. 2. Monoskopowy obraz KVR z zaznaczeniem liniowych elementów kopalni, takich jak drogi wewnętrzne, położenie i szerokość linii wydobycia różnych budynków i innych sztucznych obiektów itp. Kopalnia Pagontas

These solutions are most excellent only at the opinion of individual that decides for the choice. The scientific field of the multicriteria analysis firstly includes a theoretical background, in which the basic logic is developed for the approach of such type of problems [6]. Moreover, the main structural elements of the problem are determined and their basic attributes are then analyzed. Based on that theoretical approach a plethora of techniques have been developed, suitable for the confrontation of a wide spectrum of problems that resulted in practice. Even if the classification of these techniques in particular categories are not strict, they are distinguished in the following two main methods: the Multi – Attribute Value or Utility Theory and the Outranking approaches. The weighting method applied in both methods was the CONJOINT or HOLISTIC approach where the rank of alternatives is based on their scores in the whole set of criteria. It is based on regression analysis to derive single value functions and corresponding weights and it is very straight forward method since only simple preferential information is required by the mining expert [7].

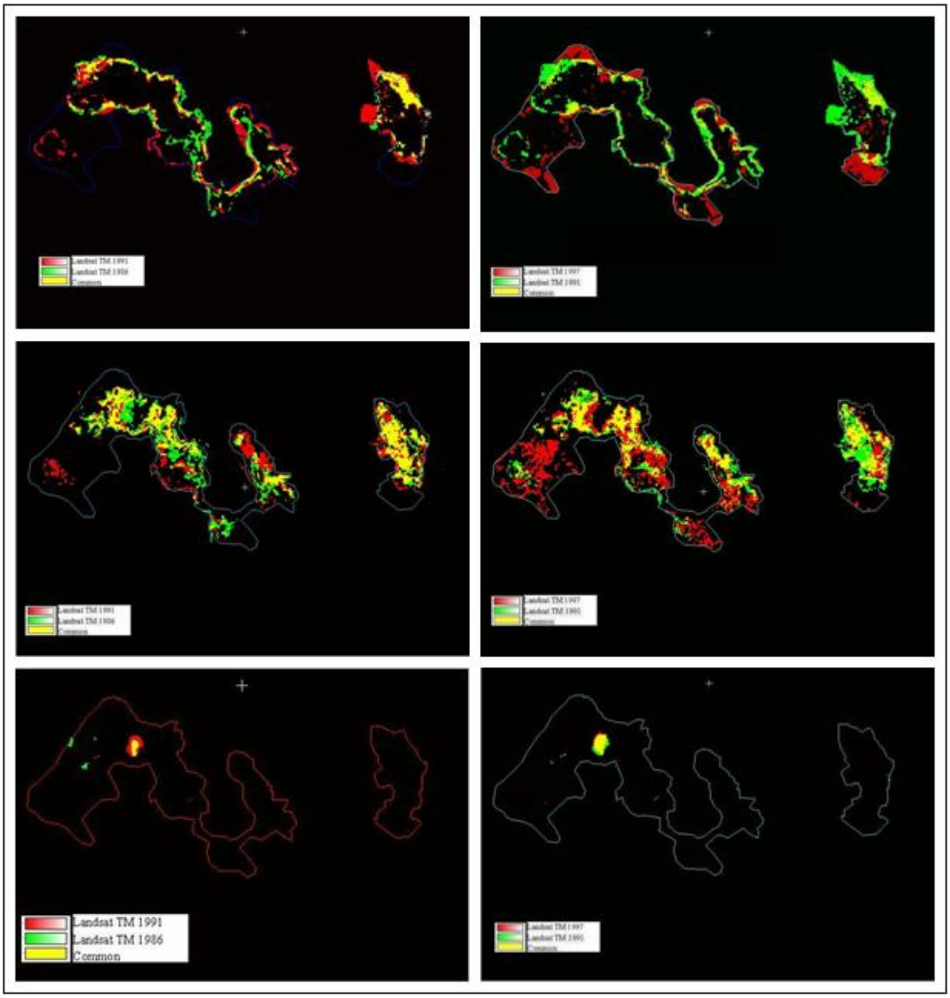

Fig. 3. From top to down and left to right: Change maps of forest (91-97 and 91-86), change map of dump sites (91-97 and 91-86) and change map of artificial lake (91-97 and 91-86). Pagontas mine

Rys. 3. Z góry na dół i od lewej do prawej: mapa zmian lasów (91-97 i 91-86), mapa zmian składowiska (91-97 i 91-86) i mapa zmian sztucznego jeziora (91-97 i 91-86). Kopalnia Pagontas

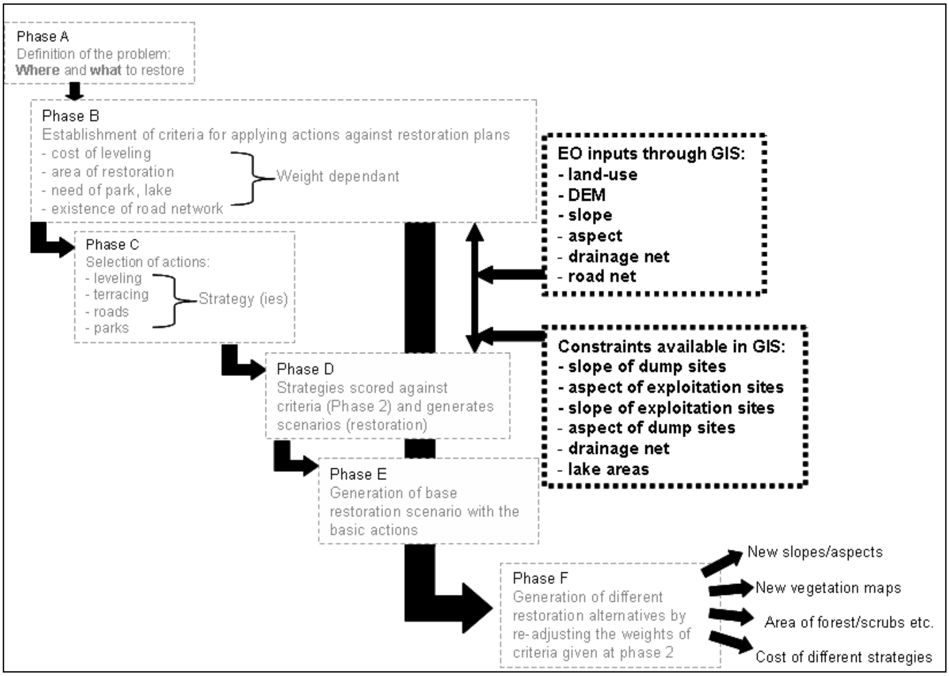

Fig. 4. Typical decision support system tree for mining restoration. Phase E introduces the multicriteria analysis. The contribution of geospatial data is indicated with bold fonts

Rys. 4. Typowe drzewo system wspomagania decyzji dotyczących rekultywacji terenów pogórniczych. Faza E wprowadza analizę multikryterialną. Udział danych geoprzestrzennych oznaczono pogrubioną czcionką

In the first method of multicriteria analysis the comparative evaluation of alternative scenarios is described in the following stages:

1st Stage: Initially, the choice of criteria is taken place. These criteria will be supposed to cover the all aspects of the examined problem and will be possible to be marked in suitable scale. Then the classification of criteria in classes is following (in our case 3 classes: the restoration at lower cost, close to initial land-use and the maximum degree of recreation). Each one of these classes is characterized by weighting factor that declares its "weight" in each scenario and is determined after discussions with the all involved institutions (in our case Larco mining company experts), taking into consideration the data of proportional cases. The sum of these factors should be equal to 100%.

Based on the above the following adding function is then resulted having the form of:

$$F(C) = \Sigma Wi \cdot Ci \quad (1)$$

where:
Ci – the individual classes of criteria,
Wi – the weighting factor of each criteria class Ci and the sum of all weighting factors should counterbalances with 1 (100%), Σ Wi =1

2nd Stage: The classes of criteria are analyzed in the individual criteria of evaluation (in our case: the restoration at lower cost is analyzed to → leveling, new benches, plantation, maintenance, road net, the close to initial land-use is analyzed to → forest or brushland and the maximum degree of recreation is analyzed to → the lake, park and new road network) for which also is determined their relative importance in the class of criteria with the help of suitable weighting factors. The sum again of these weighting factors of the individual criteria in each class is also 100%.

3rd Stage: In this stage, the analysis of all alternative characteristics (in our case: slope, aspect, elevation, and fertilization) of each individual criterion is realized and then are quantified in the scale 1-10. The smaller values correspond to the more unfavorable yield of characteristics of criterion and the higher values to the most favorable (covering with this way the all possible cases).

4th Stage: Initially the characteristics of each individual criterion for each alternative is recorded and receives a specific value (score) in scale from 1 – 10 (using also the comparison with the scale that is developed in the 3rd stage). The resulted values are then multiplied with the relative weighting factor of each criterion in each class. The resulted products are then added together for each class and in this way it is possible to generate a quantifiable way of each class of criteria. The value of each class is then multiplied with the corresponding weighting factor and through the adding function approach a measurement of the total effectiveness of each choice is realized. Based on this grade the rank of all alternative scenarios is made possible having the more favorable the one that exhibits the higher value [8].

The second method of outranking approaches is based on the per pairs comparison of choices in each individual criterion taking into account their records and the "endocriteria" preferences of the decision maker, as these are expressed with the thresholds of indifference and/or preference [6]. The characteristic of the Outranking Approach methods is that the comparison is becoming in the initial scale of measurement of records (quantitative or qualitative) without the reduction to the [0, 1] interval. The indicator that is resulting from the comparison per criterion is then composed to a total dual indicator taking into consideration the weighting factors of criteria.

The dual indicators characterize the pairs of choices (A, B) and determine in the [0, 1] interval the degree in which the hypothesis "Alternative restoration scenario A is at least so much so good as alternative B" is in effect. Depending on the method and their precise way of calculation, these indicators are named indicators of preference or indicators of agreement (as for the hypothesis). An alternative A, that presents high values of indicators of preference in relation to the remaining alternatives is characterized by a relative outranking, while on the contrary other alternatives that do not confirm the hypothesis in an important degree, are judged as inferior. Consequently, the final stage in the Outranking methods is the treatment of dual indicators so as to result relations of "supremacy" and the final classification of alternatives.

4. Results

The results on the satellite data capabilities and how these can match the three major mining activities requirements are summarized in the following table.

The Utility Theory produced the most accurate results that were confirmed using the KVR-1000 image, field work and the two Quickbird images acquired in 2002 and 2007. This method highlighted, as necessary to be restored, the dump sites with slope > 45° (answering to where the restoration has to be applied) and proposing as restoration alternative the leveling and plantation (answering to what type of land-use).

Table 1. Satellite data capabilities versus mining activity requirements
Tabela 1. Możliwości danych satelitarnych w porównaiu z wymaganiami kopalnianymi

Mining activity requirements			**Satellite data capabilities. Revisit time, spectral and spatial resolution**					
			1986÷1998				1999÷2007	
Pre-mining	Mining	Restoration	Satellite data produced scale	Revisit (days)	Availability	Accuracy	Satellite data produced scale	Accuracy
* exploration of new aras *general mapping of relief, geology and lithology including landslides			Landsat4/5 TM 741-TM6 LISS-3 543 JERS1 OPS **1: 100000 & 1: 50000** AIRBORNE (CASI/MIVIS/DAIS/AVIRIS)	16 24 44 N/A	1982 1996 1992 1996	30-120m 25 m 20 m	Landsat-7 TM 1: 50000 ASTER SWIR/TIR 1: 50000 SPOT-5 PAN (1/10.000)	15-60 m 2-5 m
* feasibility studies + environmental impact assessment studies - road network - dump sites			SPOT PAN **1: 25000** IRS-1C PAN **1: 15000**	26 5	1986 1996	10 m 8 m	SPOT-5 PAN (2002)	2-5 m

Table 1. cont.
Tabela 1. cd.

Mining activity requirements			Satellite data capabilities. Revisit time, spectral and spatial resolution					
			1986÷1998				1999÷2007	
Pre-mining	Mining	Restoration	Satellite data produced scale	Revisit (days)	Availability	Accuracy	Satellite data produced scale	Accuracy
* Environmental assessment => - Assessment of restoration senario - land-cover, land-use mapping - assessment of land productivity			KVR 1000 PAN KFA 3000 PANDD-5 PAN **1:5000**	No systematic	1984 1978	2 m 3 m 2 m	QuickBird (2001), <1:5000OrbView-3 (2003) IKONOS-1 (1999) <1:5000 **(tasking plan-revisit 3 days)** Landsat-7	1 m 1 m 1 m

Table 1. cont.
Tabela 1. cd.

Mining activity requirements			Satellite data capabilities. Revisit time, spectral and spatial resolution					
			1986÷1998				1999÷2007	
Pre-mining	Mining	Restoration	Satellite data produced scale	Revisit (days)	Availability	Accuracy	Satellite data produced scale	Accuracy
* creation and			Landsat-5 TM 741	16	1982	30 m		15÷30 m
updating of:			LISS-3 (IRS-	24	1996	25 m	SPOT-4/5	
- geology maps			1C)JERS1-OPS	44	1992	20 m		
- mineral maps			SPOT XS	26	1986	20 m		2÷5 m
- soil maps			**1: 100000**	N/A				
- drainage network			**1: 50000**					
- hydrologic maps					1996	20 m		
			AIRBORNE					
			(CASI/MIVIS/DAIS/					
			AVIRIS)				TerraSAR-X	
			1: 10000				(2007)	1 m
				26 (3)	1986			(DEMs: ±1-
*DEMs +			SPOT 1A/1B	14(5)	1996		ENVISAT	3 m)
Slope map			IRS PAN	44	1992	10-20 m	RADARSAT II	
100-m resolution			JERS OPS-band4	35/3	1991			8÷30 m
30-m resolution			ERS 1/2-amplitude	24	1996			(DEMs: ±1-
			RADARSAT	various	1991			3 m)
			InterfSAR					

Table 1. cont.
Tabela 1. cd.

Mining activity requirements			Satellite data capabilities Revisit time, spectral and spatial resolution					
			1986÷1998				1999÷2007	
Pre-mining	Mining	Restoration	Satellite data produced scale	Revisit (days)	Availability	Accuracy	Satellite data produced scale	Accuracy
	Mining site monitoring, benches extension, dump sites monitoring: •slope failure •benches damages •leakages		SPOT PAN **1: 25000** IRS-1C PAN **1: 15000** KVR 1000 PAN KFA 3000 PAN **1:5000**	26 5 No systematic	1986 1996 1984 1978	10 m 8 m 2 m 3 m	SPOT-5 QuickBird, <1:5000 OrbView-3 IKONOS-1 <1:5000	2÷5 m 1 m 1 m 1 m
	Mining site visualization		**DEMs** SPOT 1A/1B IRS PAN JERS OPS-band4 ERS 1/2-amplitude RADARSAT InterfSAR	26 (3) 14(5) 44 35/3 24 various	1986 1996 1992 1991 1996 1991	10÷20 m	QuickBird, <1:5000 OrbView-3 IKONOS-1 <1:5000	(DEMs: ±1÷3 m)

Table 1. cont.
Tabela 1. cd.

Mining activity requirements			Satellite data capabilities Revisit time, spectral and spatial resolution					
			1986÷1998				1999÷2007	
Pre-mining	Mining	Restoration	Satellite data produced scale	Revisit (days)	Availability	Accuracy	Satellite data produced scale	Accuracy
		* Restoration	Landsat-TM 741	16	1982	30 m	QuickBird, <1:5000	1 m
		*new land for	SPOT PAN	26	1986	10 m	OrbView-3	
		agriculture	1: 25000				IKONOS-1	1 m
		*Assessment :	IRS-1C PAN		1996	8 m	<1:5000	1 m
		- aesthetic quality	1: 15000					
		- environmental	KVR 1000 PAN	5	1984	2 m		
		compliance	KFA 3000 PAN		1978	3 m		
		[through diachronic	1:5000					
		DEMs, land-cover,						
		land use maps and	**DEMs**				QuickBird, <1:5000	
		NDVIs]	SPOT 1A/1B	26 (3)	1986		OrbView-3	
			IRS PAN	14(5)	1996	10÷20 m	IKONOS-1	(DEMs:
			JERS OPS-band4	44	1992		<1:5000	±1÷3 m)
			ERS 1/2-amplitude	35/3	1991			
			RADARSAT	24	1996		RADARSAT	
			InterfSAR	various	1991		TerraSAR-X	
								(DEMs:
								±1÷3 m)

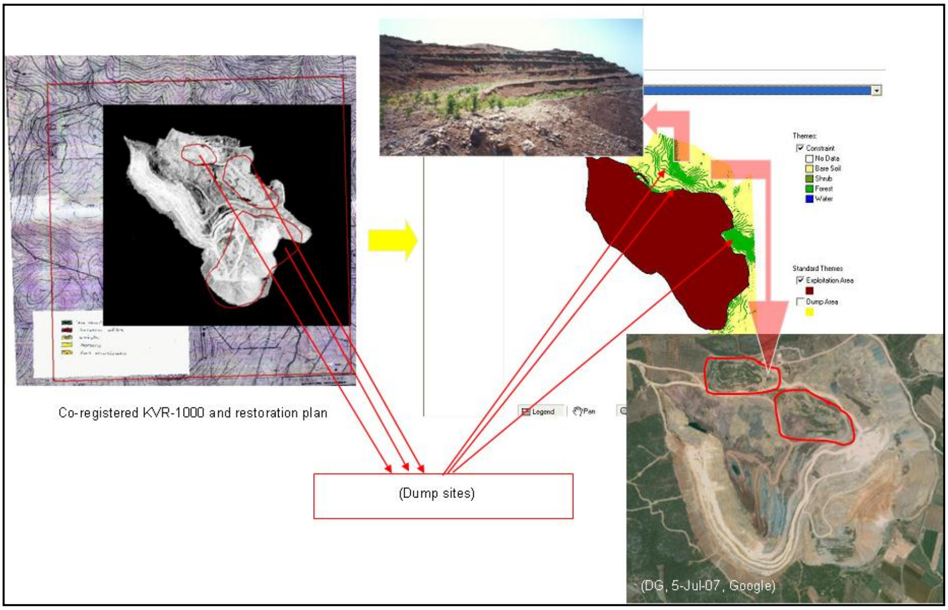

Fig. 5. Verification of restoration scenario at Isoma mining site. The subset at the left is a KVR-1000 image coregistered with mining company restoration land-use scenario map, the subset at the top central is the photographic documentation of the planted benches, the subset at the central right is the bitmap produced by the Utility Theory multicriteria analysis showing in yellow the dump sites and in green the planted benches and the lower right subset is the Quickbird image of 2007 verifying in red polygons the restored dump sites with plants

Rys. 5. Weryfikacja scenariusza rekultywacji w kopalni Isoma. Po lewej obraz KVR-1000 zarejestrowany wraz mapą rekultywacji sporządzoną przez zakład górniczy u góry dokumentacja fotograficzna rozpoczętej rekultywacji, u góry po prawej bitmapa będąca rezultatem analizy wielokryterialnej Utility Theory (na żółto zaznaczono zwałowiska, na zielono obsadzone stanowiska) na dole po prawej znajduje się obraz weryfikujący Quickbird z 2007 roku (na czerwono zaznaczono zrekultywowane zwałowiska)

5. Conclusions

As the satellite imagery and its geospatial derivatives becoming more and more available at a fraction of a cost including the efforts of gathering it, the more and more use will be happen by mining actors who they are looking for cost-effective, reliable and up-to-date information sources. Valuable information can be gained from the analysis of remotely sensed data to monitor pre-mining, mining and post mining activities.

Discriminating factors for satellite data use over conventional and field surveys are the spatial, spectral and the revisit resolution, the digital format and global coverage and availability through global web based mapping tools and databases such as Google and Bing. The more channels are used over a mine setting and its surroundings, in a frequent revisit time intervals and with great detail (lets say IKONOS-2, GeoEye, Quickbird, WorldView-1 and WorldView-2) the better feature extraction information such as mine-land use, conveyor belts, man-made structures, benches, sparsely planted areas and 3D volumes generation within the mine site itself will be achieved. And the more reliable and timeliness information is extracted the better performance is expected to be gained by the analysis of spatial decision support systems where most of the mining engineers and managers rely on to get feedback on their restoration plans. Cost-effectiveness also relies on which method a DSS should use in order to be easily assimilated by the mining expert, which is translated to a method that is straight-forward, simple, understandable with the less defensible and well balanced restoration alternatives [9]. What differentiates the methods of Outranking approaches from the methods of Utility Theory is that the scale of characterization and evaluation of alternatives, it is not a total weighed “record”, but an indicator of composition of deciding preferences. This means that the weighting factors in the methods of Outranking Approaches play a different role. More specifically, they do not have the character of compensation factors between the records in the individual criteria and for that reason, it is not used any compensation method to extract them. On the contrary, they imply the degree of contribution of each criterion in the configuration of total indicator of preference or agreement.

Because of the extended model of preferences that was followed, the transitivity hypothesis is not valid among the Outranking approaches. If the decision maker judges that alternative restoration A surpass B, and the alternative B the C, this does not essentially means that alternative A surpasses the C. This happens when the scenario "alternative A, is as good as alternative C", is not sufficiently confirmed due to the contradictions that resulted from their dual comparison in the individual criteria. Consequently, the initial classification of choices in the Outranking Approaches is not complete, as it is including no comparable choices. Although several studies have shown that even if this characteristic from first opinion can be considered as negative, in reality it provides useful information to the decision maker to find alternatives focusing on their strong and weak scores evaluation [10]. However is our case, simplicity and transparency were the most important issues to stimulate the mining expert or environmental controller to use and justify the satellite data and multicriteria analysis towards the mining restoration or the environmental compliance. The well assimilated Utility Theory multicriteria analysis produced fast reliable results that were verified by satellite data and field work and is recommended for surface mining restoration.

References

1. **Almer A., Banninger C., Fernandez-Turiel J.L., Llorens J.F.:** *Automatic 3-D information extraction of open-cast mining infrastructure from simulated IKONOS data*. EOS/SPIE Symposium on Remote Sensing (Europto Series), 20÷24 September, Florence, Italy (Bellingham, WA: SPIE), pp. 254÷260. 1999.
2. **Spyropoulos N., Valmis S., Ganas A., Metaxas G.:** *Monitoring surface mining using satellite remote sensing change detection techniques*. The Evia Island Project, Greece. IHEPI Journal. 2010.
3. **Sengupta M.:** *Environmental impacts of Mining: Monitoring, Restoration and Control*. Lewis Publ. Boca Raton, Florida, 494 pp. 1993.
4. **Ganas A., et al.:** *The use of earth observation and decision support systems in the restoration of open cast nickel mines in Evia, central Greece*. International Journal of Remote Sensing. Vol. 25, No 16., 3261-3274. 2004.
5. **Katta G. Murty:** *Optimization Models For Decision Making: Volume 1*. Department of Industrial And Operations Engineering, 1205, Beal Avenue, University of Michigan, Ann Arbor, MI-48109-2117, USA. 2008.

6. Life Programme. Development of Management Systems for High Priority Waste Streams in Cyprus. Life Third Countries. Life03 TCY/CY/000018 project. European Commission. 2005.
7. **Hobbs F.B., Meier P.:** *Energy Decision and the Environment. A guide to the Use of Multicriteria Methods*. Kluwer Academic Publishers. 2000.
8. **De Vente J., Aerts J.C. J. H.:** *Environmental restoration of a surface mining area. The application of remote sensing and GIS in a management information system.* In MIS 2000, GIS and Remote Sensing, MIS 2000 Conference, Lisbon, June 2000, edited by C. A. Brebbia and P. Pascolo (Southampton: WIT Press), pp. 393÷402. 2000.
9. **Spyropoulos N., et al.:** *Extracting real world model values from EO data, aiming to assist decision support systems in the restoration of open-cast nickel mines*. IATED Journal. EDULEARN10. 2010.
10. **Spyropoulos N., et al.:** *Land reclamation of surface mining based on imagery intelligence and spatial decision support systems*. World Transactions on Engineering and Technology Education, Vol. 8, No. 1. 2010.

Ekonomicznie efektywne metody podejmowania decyzji dotyczących rekultywacji terenów pogórniczych przy użyciu danych geoprzestrzennych i analizy wielokryterialnej

Streszczenie

Opłacalność jest bardzo ważnym pojęciem, który spółki węglowe uważają za kluczowy. Podstawowa zasada rekultywacji zniszczonego terenu to uczynienie tego minimalnymi kosztami. Dane geoprzestrzenne mogą odgrywać ważną i oszczędzającą koszty rolę w monitorowaniu aktualnej działalności górniczej oraz w tworzeniu map rekultywacji przy użyciu technik automatycznej klasyfikacji i porównania kilku zbiorów danych teledetekryjnych, przy minimalnej ilości pracy w terenie. Dane geoprzestrzenne mogą również wspomagać również inżynierów górniczych w wyborze, które obszary poddawać rekultywacji i do jakiego typu użytkowania. Oprócz tego procesu doradczego, wymagana jest prosta metodologia do symulacji głównych etapów podejmowania decyzji przez ekspertów górniczych (inżynier, kierownik) podczas tworzenia planu rekultywacji. Metodologia ta powinna gromadzić dane geoprzestrzennych i musi być bardzo prosta, zrozumiała i łatwa do uruchomienia przez specjalistę górniczego lub administratora z władz krajowych lub

lokalnych, którzy sprawdzą poprawność środowiskową działalności górniczej i będą nadzorować zezwolenia na eksploatację zasobów naturalnych na danym terenie. Metoda musi umożliwić decydentom rozwiązywanie problemów, które wynikają z błędnie przyjętych celów w sposób matematyczny. W ten sposób zmniejszona zostanie tendencja do ignorowania lub niewłaściwej interpretacji wiele atrybutów, nawet tych najważniejszych, podczas tworzenia rankingu możliwości. Niniejsza praca pokazuje skuteczności kombinacji danych geoprzestrzennych i analizy wielokryterialnej do procesu podejmowania decyzji o rekultywacji terenów pogórniczych w sposób uzasadniony i wyważony.