PROJECT FINAL REPORT

Grant Agreement number: 244166

Project acronym: IMPACTMIN

Project title: Impact Monitoring of Mineral Resources Exploitation

Funding Scheme: FP7-CP-SICA

Period covered: from 01/01/2010 to 31/12/2012

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4.1 Final publishable summary report

Executive summary

In Europe, mining has a long tradition since mineral resources have always been needed (and will be so) for economic development. Political will strives that Europe ensures itself in the mid- and long-term with the sustainable supply of raw materials in order to support growth with innovation. Social and environmental impacts of mining will continue to be an important issue in the 21st century as well. IMPACTMIN project recognized that old and new deposits and their surroundings require adequate management and stakeholders and local people need a good relation with the industrial-economic activities related to mineral resources exploitation.

Impact Monitoring of Mineral Resources Exploitation is one of the most exciting topics of the raw materials sector recently. IMPACTMIN (FP7) followed up on the findings of MINEO (FP5) and PECOMINES (FP6) projects to investigate the state-of-the-art methods for demonstrating best practices and reveal recent methodological and technical advancements in the field of impact monitoring and natural resources management. The IMPACTMIN project surfaced actual issues on how the environmental and social impacts interact and what kind of legislative aspects control this sector.

IMPACTMIN examined to what extent "responsible mining" is implemented by using real-life case studies. Carbon footprint reduction practices and people's perception on mining have been investigated in order to understand where gaps or challenges can be in implementing different - to date voluntary - schemes that can be applied when practicing Corporate Social Responsibility (CSR) in the mining industry.

IMPACTMIN addressed the need for the provision of timely data and products to stakeholders; wherein decision making is based on a coordinated, comprehensive and sustained Earth Observation and information, which is the main objective of the Global Earth Observation System of Systems (GEOSS). IMPACTMIN project has investigated the current state-of-the-art technology to monitor subtle changes in the environment caused by mining activities and how these could be properly reported. IMPACTMIN has developed new methods and a corresponding toolset for the environmental and socio-economic impact monitoring of mining activities using also Earth Observation (EO) techniques. Cutting-edge technology has been employed for the combined use of satellite EO data, aerial measurements and Unmanned Aerial Vehicles (UAVs).

Mine wastes, abandoned mines, current and future mining sites are continuously impacting their surroundings and their future management is still to face with proper regulation and reclamation actions. Recent research showed that Europe, with a proper strategy, will continue mineral extraction at several old and new locations thus legislative and research actions are needed for supporting the future sustainable raw material exploitation.

Project context and objectives

ImpactMin (www.impactmin.eu) has developed methods and a corresponding toolset for the environmental and socio-economic impact monitoring of mining activities using Earth Observations (EO). The proposed methods were validated at four demonstration sites corresponding to different scales and scope. The theoretical advancement in science and technology is made public knowledge with the help of a free multimedia interactive e-learning programme, whereas the tools and foreground knowledge generated by the project is commercialised by the participating SMEs.

Specifically, the ImpactMin project aimed to:

- *Monitor the needs and requirements of stakeholders;*
- *Spatially integrate socio-economic aspects of mining operations;*
- *Define a set of tools and services that are based on the feasible use of the best available technologies, stakeholder requirements and existing standards;*
- *Validate these tools and globally demonstrate their applicability at four high-profile demonstration sites; and*
- *Develop and implement an accessible and free-of-charge multimedia e-learning programme for remote sensing and mining professionals.*

The Project presented showcase results on how different mining environments (abandoned, pre-operational etc.) represent challenges from environmental and socio-economic points of view. Four demonstration sites have been examined within the framework of the ImpactMin Project. These are introduced below.

1. Kristineberg (Sweden)

Geography: The Kristineberg mining area (~300 ha) is located at approximately 175 km south-west of Lulea in Lycksele municipality, a municipality in Västerbotten County in northern Sweden. The mining area comprises a large tailings area and five mines, a large central industrial area which includes an old concentrator and three open pits. The population of the municipality is 12,506 and the surface area of the whole municipality is 563,600 hectares, therefore the population density is 2.2 people per hectare. The topography can be described as mostly hilly with an abundance of forest and scattered lakes.

Current situation: Today, the ore is transported to the Boliden concentrator using 50-ton highway trucks, which are also used for transporting backfill tailings to the mine. The main products recovered from the ore are zinc, copper and lead concentrates. Five ponds are located along a valley between two mountain ridges. Initially, the tailings were deposited in two ponds; later, new ponds were constructed in the south of the confluence between Rävlidmyrbäcken and Vormbäcken.

At closure, the tailings area consisted of five individual ponds containing pyrite rich tailings, including three old drained ponds containing weathered tailings, one recently operated pond containing unweathered material, and one pond containing substantial quantities of precipitates from the treatment of acidic mine water.

Proposed activities: The latest technology of UAVs is proposed to sample vegetation at a mining site and at several localities downstream the mining site. Localities upstream the mining site served as reference sites as well as the localities at different cardinal points of the compass.

2. Rosa Montana (Romania)

Geography: Rosia Montana is a small village in the forested mountains of western Romania. The site of gold deposits is believed to be the largest in Europe. The Rosia Montana Project (RMP) is located near the village of Rosia Montana in west-central Romania, approximately 50 km northwest of the regional capital, Alba Iulia, in the Metaliferi Mountains, which belong to a larger, regional mountain unit called the Apuseni Mountains of Transylvania.

Current situation: The Rosia Montana region represents a complex geological-mining environmental interaction area, exhibiting over two millennia of surface and underground mining and milling operations. Mountainous, vegetated and water-saturated setting of the area gives additional complexity in characterizing the area from the environmental standpoint. Due to recent developments and planned mining operations, Rosia Montana is expected to be the largest open-cast gold mine in Europe.

Proposed activities: A combination of EO measurements (at different ground scales) and data processing (including historical records) was used to assess the environmental legacy of over two millennia of mining in the context of a new operation is expected to be launched in the near future.

3. Mostar Valley (Bosnia and Herzegovina)

Geography: The city of Mostar, located in the southern portion of Bosnia and Herzegovina (BiH), was one of the main areas of aluminium extraction, fabrication and aircraft industries. Mostar is situated on the river Neretva and is the fifth-largest city in the country. Three demonstration sites are proposed for investigation. The first is on the northern part of the city, which is a red mud disposal site. The second one is an abandoned coal mine near the city center, and the third one is in the south of the city and is a planned lignite mine.

Current situation: The second site is an ongoing rehabilitation project in the former coal mine Vihovici, a site of great threat to the local population and the environment due to toxic gas emissions, landslides and volatile organic compounds (VOCs) into the water supply.

Proposed activities: The sites were selected for follow-up identification using satellite imagery, hyperspectral remote sensing, spectroscopy, field-spectroscopy, and geochemical sampling. The complex geo-environment (mineralogy, wastes, surface water) and the remediation efforts have been thoroughly studied.

4. Orenburg (Russia)

Geography: The Ural, in geological and geographical meaning, is a fragment of Paleozoic fold area expressed as a mountain chain and has a width of 150 to 300-400 km and a length of about 2,000 km. South Ural Mountains of Russia (700 km) contain mainly massive sulphide deposits. It has a continental climate, with extremes of temperature, and lies within the South Taiga and forest-steppe zones.

Current situation: Today, many of the mineral deposits are exhausted or are uneconomic in current world markets. The extraction technologies used in most operations are inefficient and environmentally unsound. In certain areas, pollution from past and current mining-related activities is known to be heavily impacting on human and environmental health. From a political and sociological perspective, large-scale closure of operations is currently impossible as mining industries are major employers, which underpin the economy of the region.

ImpactMin addressed the situation in the following areas:

The South Ural Mountains of Russia has been a centre for mining and the production of precious and base metals for well over 3,000 years. In the early- to mid-20th century, production activities were heavily intensified with little long-term planning or consideration for the environment. The extraction technologies used in most operations are inefficient and environmentally unsound. In certain areas, pollution from past and current mining-related activities is known to be heavily impacting on human and environmental health. From a political and sociological perspective, large-scale closure of operations is currently impossible as mining industries are major employers, which underpin the economy of the region.

- Karabash, located in the South Taiga vegetative zone of the Chelyabinsk district of Russia, is host to a large copper smelter and several abandoned mine workings, tailings dams, waste dumps and stockpiles of concentrates. In 1995, the Russian Ministry of the Environment and Ecology designated the town as an ecological disaster zone.
- Mednogorsk, located in “steppe mountain” zone, is host to a large copper smelter and several abandoned mine workings (with two open pits with pit lakes’ water depth of 39-45 m), tailings dams, waste dumps and stockpiles of concentrates.

Proposed activities: The territory of Southern Ural represents a continuous mining area with several large mining operations, broken landscapes, huge environmental problems, and due to recent mine closures, enormous socio-economic difficulties. An essential task was to demonstrate the use of spatial modelling and applied remote sensing methods for the combined monitoring of environmental and socio-economical changes.

The Project’s scientific challenge was to use cutting-edge remote sensing technologies to develop a cost-effective, reliable and replicable approach for monitoring the impact of mining activities on the environment through time, in order to identify, predict and prevent potentially serious consequences for the natural and human environment. The socio-economic investigation aimed at understanding peoples’ perception on mining and reveal how the industry plays its role in human relations in the context of “responsible mining”.

In addition to WP1, Project Management work package (WP), IMPACTMIN had eight work packages with the following scopes and objectives:

- Work Package 2 (WP2) was mainly dedicated to identify the requirements and expectations that mining companies, their service providers and monitoring authorities have in terms of remote monitoring.

- Work Package 3 (WP3) was to create a better understanding of the socio-economic impacts of mining, investigating how we can develop a Corporate Social Responsibility (CSR) policy that will incorporate and disseminate best practices within the industry.

- Work Package 4 (WP4) was for generating a scientific knowledge pool that eventually served as the basis for the development of harmonised methods in the impact monitoring of mining activities. This knowledge pool was to be derived from mineral resources exploration methods, EO-based environmental monitoring techniques and by "translating" research results from other fields of science with a possible applicability in ImpactMin.

- Work Package 5 (WP5) was to develop a technical conceptual framework for the use of aerial methods in the monitoring of the environmental impacts of mining and mineral resources exploitation. The framework would consist of the evaluation of the usability/feasibility of airborne systems based on the evaluation of over two decades of scientific and engineering knowledge pool and gear the information towards demo-site implementation.

- Work Package 6 (WP6) was dedicated to develop, validate and deploy harmonised methods for the assessment and monitoring of environmental impacts from mining operations based on identified stakeholder needs and the knowledge pool generated in WP4 and WP5 taking into account the limitations of satellite, aerial and in-situ measurements.

- In WP7 the ImpactMin toolset and methods on selected test sites were calibrate and demonstrate using harmonised methodologies and a comparative research design.

- WP8 was dedicated for the dissemination of information about the Project, its objectives, the approaches and results through a combination of electronic and traditional methods.

- In WP9 the partners deployed a simple but robust and highly cost efficient e-training programme based on the results of ImpactMin in order to bridge the gap between the developed new concepts and the stakeholders, and support the fast take-up of the developed tools.

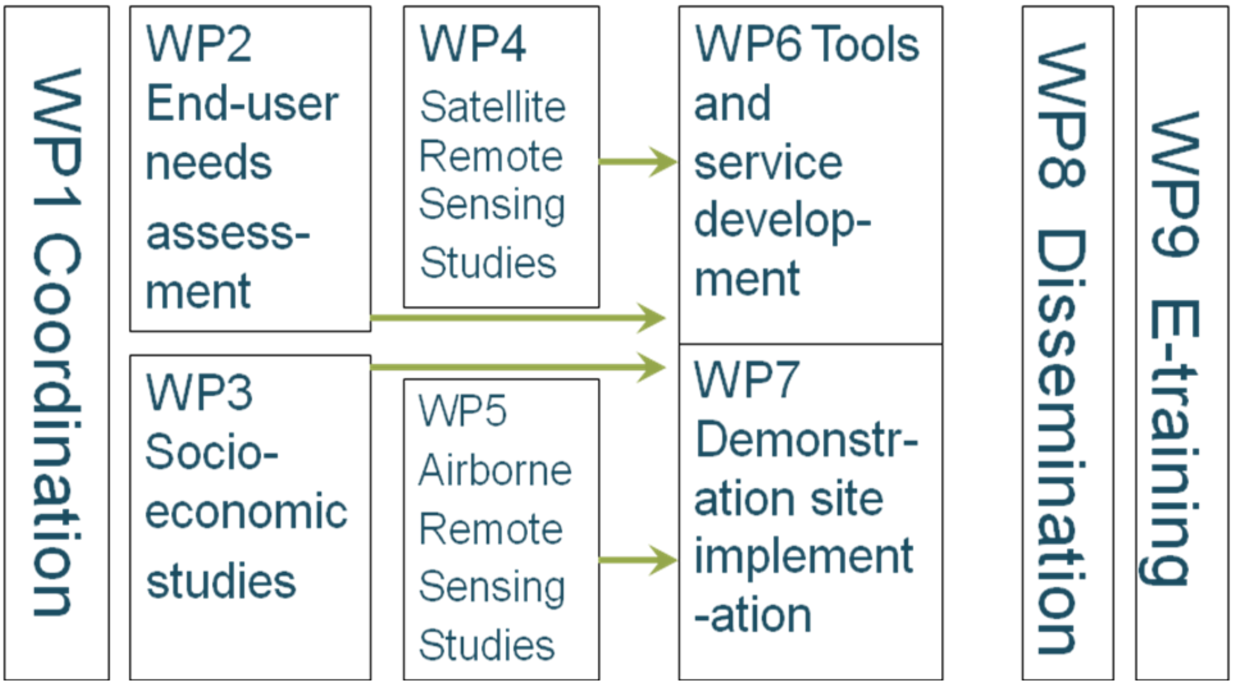
Main S&T results/foregrounds

Overview of the project activities

The project approach facilitated the development and demonstration of new technologies together with the dissemination of best practices, technology transfer, development of international co-operation to the broader international community active in the field of mineral resources management and earth observations. These activities hinge on the use of the latest advances in remote sensing science and access to data acquired by various Earth observing satellites to characterize the state and evolution of changes in the environment. Developing a reliable and harmonised pool of applied EO knowledge is to foster greater environmental awareness of available mineral resources and a better monitoring of sustainability as well as competitiveness aspects. In doing so, the Project provides services and products (in the mid-/long-term as well) that are combined, customised, and supplemented by various information elements to create deliverables designed to meet specific policy driven requirement of users.

The socio-economic research (WP3) served as a backdrop for the two preparatory work packages, where ethical and transparency issues were addressed. ImpactMin was committed to promote environmentally responsible mining, which can only be achieved if the socio-economic conditions that proceed and follow mining operations are properly revealed and taken into account. Thus, the cost/benefit assessment of investments into environmental monitoring versus public acceptance and awareness had to be taken into account.

The below figure shows the context between Work Packages (horizontal WPs are also included):



WP3 S&T results

The purpose of this work was the premise that in the future there will be a need to look to mine more within Europe as a way of ensuring security of supply of mineral resources. Thus, by finding out what people think of mining and how it has affected their lives, we have a way of relaying this information to mining companies and governments and allowing them to successfully implement policies that can mitigate negative impacts and maximise the positive benefits that mining can have. By having an awareness of and knowledge of how mining affects people and communities, mining companies can look at how what are the key factors in developing successful working relationships with different stakeholders.

Reports:

D3.1 Report on socio-economic indicators, drivers and best practice across the chosen sites
D3.2 Report on study of mining and society and implications
D3.3 Report on best practice for carbon footprint reduction

Activities and results

Mining & Society – cross-national, comparative analysis of public understanding of, and attitudes towards activities in the extractive industry

Workshop with key project participants

In May 2010 (24 – 27) the University of Exeter (UNEXE) organised the first official workshop for the relevant partners. The general focus of the workshop was on to define the socio-economic survey framework and in particular:

- to assess what the issues were at each of the demo sites
- to identify suitable stakeholders to interview at each of the demo sites
- to gain input from different partners into what questions should be asked in the ImpactMin WP3 survey

This workshop was essential to developing a work plan and progressing WP3. It was decided that the survey needed to be designed to include a comparative list of questions in addition to questions that addressed specific issues to each of the site.

One of the fundamental drivers behind the entire ImpactMin project was the geopolitical situation arising that may mean that in the future there will be a need to mine more within Europe as a way of ensuring the security of supply of mineral resources. By having an awareness of, and knowledge of how mining affects people and communities, companies can look at what are the key factors in developing successful working relationships with different stakeholders. Also it was concluded that there are an increasing number of social and environmental management 'voluntary' codes that mining companies can chose to follow, in addition to legislation that they have to abide by. Having the ability to adhere to voluntary Corporate Social Responsibility (CSR) guidelines will help a company maintain their 'social license' to operate in the eyes of the stakeholder groups they work alongside.

Reflecting the above indicated issues the research that was undertaken in WP3 has been quite complex, involving a cross-comparative survey administered at all of the demo sites, in addition to interviews and focus groups to enable more in-depth issues to be explored. The interviews and focus groups have involved key stakeholders and informal decision leaders within the mining or metal processing communities. Each survey used at the seven sites (including Cornwall) contained generic questions to enable basic demographic information to be collected, alongside generic questions to ascertain and compare people's views of mining. Further questions were asked at each of the sites to address issues specific to each individual site (the specific issues have been identified by correspondence with partners working at these sites and add interest and breadth to the cross-comparative questions).

Demo sites from Bosnia Herzegovina (Vihovići), Romania (Rosia Montana), Russia (Gay, Karabash, Mednogorsk), Sweden (Kristineberg) and the UK (Cornwall) from a social perspective, were sites providing a variation in stages of mining (from exploration phases through to post-mining projects). Timeline and contributors of WP3 fieldworks:

- Rosia Montana: 20 - 25 June 2010
- Gay, Karabash and Mednogorsk: 12 - 22 July 2010
- Kristineberg / Malå: 8 - 15 September 2010
- Vihovići: 18 - 26 September 2010
- Cornwall: Summer - Autumn 2010

Table - Surveys and interviews completed across the ImpactMin demo sites

Country	**Study area**	**Number of surveys completed**	**Number of interviews completed**
Bosnia Herzegovina	Vihovići	124	5
Romania	Rosia Montana	97	15
Russia	Gay	41	2
Russia	Karabash	40	2
Russia	Mednogorsk	32	1
Sweden	Kristineberg	66	11
UK	Cornwall	303	13
Total		703	49

Deliverable 3.1 reported on the socio-economic indicators, drivers and best practice in responsible mining, reviewing background information on what the socioeconomic impacts of mining can be, including how

mining companies develop corporate social responsibility programmes and their practices of engaging with stakeholders. Assessing stakeholder theory, including how stakeholders interact and influence each other, is key to understanding the role of CSR within a company and was also discussed within the context of this report. Descriptions were provided of the ImpactMin demo site descriptions within this report, helping create a better understanding of vital background information to aid the interpretation of the findings of the research that was carried out in Deliverable 3.2.

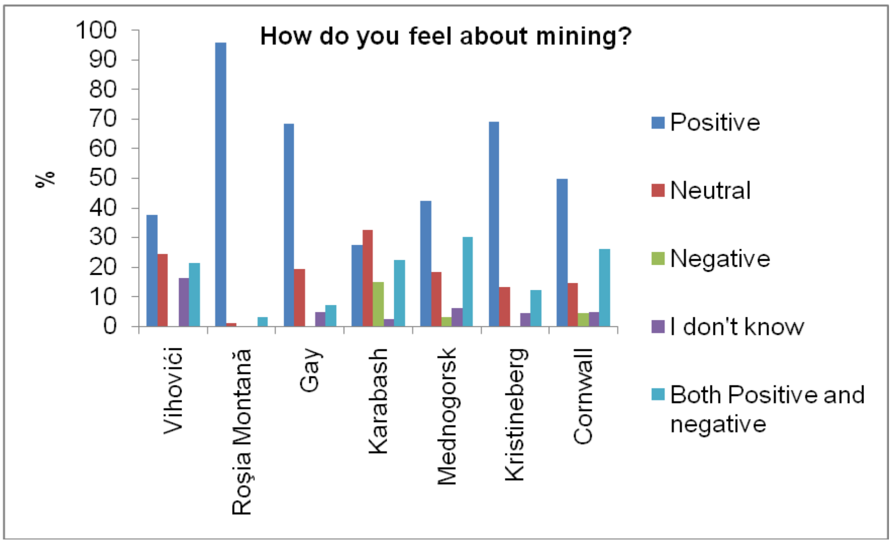
Assessment of the status of incorporating social and political issues into corporate strategy

This sub-task focused on presenting results of the surveys and interviews carried out across the ImpactMin demo sites. Results were meant to determine:

1. The level of concern for environmental issues.
2. How best to disseminate results of the remote sensing on the environmental impacts of mining.

Results shown in Report 3.2 revealed what people think of mining and how mining has affected their lives across the seven ImpactMin demo sites. These findings provided information on what the socio-economic impacts of mining have been at each of the sites, including how mining companies develop social responsibility programmes, how they engage with different stakeholders and what the stakeholder perceptions are from people who have participated in the interviews and surveys. Overall, because the socio-economic impacts of mining are tied to the environmental impacts that mining may have, many of the questions in the survey and interviews explored how people feel about their physical environment, including assessing their perception of what changes mining has had on the physical environment and how these changes have affected their lives.

The findings from WP3 show how mining affects people in many different ways and how people have very different perceptions and perspectives of mining in general, and more specifically on how mining has affected their lives. The understanding people have of mining differs across the sites used in the ImpactMin project. There is a variation across the sites relating to how people felt in their ability to express their views.



An example on the results of the ImpactMin survey in 2010 asking for local people's views on mining.

Across all of the sites, except Vihovići, the majority of people felt that mining was an important part of their identity / heritage / tradition. Respondents in Mostar, relating to Vihovići, as discussed above, have been influenced by inwards and outwards migration of residents from Mostar. Across the other sites, Cornwall and Rosia Montana have both had active mines for several thousands of years and Gay, Karabash, Mednogorsk and Kristineberg, are all towns / villages that grew and exist because of mining and related industries. This provides the link and basic premise for residents of these areas having strong connections with mining.

Discrepancies were evident across the demo sites relating to the expectations stakeholders have of the mining company, highlighting the idea that CSR is fluid and that it cannot be defined into a one size fit all approach. The present study has clearly identified that CSR needs adapting to the context of an individual site. Without CSR being adapted to the specific context of stakeholders at a site, CSR is unlikely to work.

Work Package 3 gave also site specific conclusions:

- Relocation of people in order for projects to proceed is complex and has potentially been one of the most difficult issues e.g. Rosia Montana.
- In Rosia Montana, it appears that a lot of the opposition comes from outside of the community. Governments need to be aware of this and listen to the views of people who are actually being impacted whilst considering the bigger picture and in particular, the long term needs at a site.
- Developing purpose built mining towns like Kristineberg creates particular issues post mining.
- Karabash, in particular, and Mednogorsk to a lesser degree, are examples of why smelters should not be built right next to towns and cities and why the location of smelters needs appropriate consideration relating to chimney stack height and nearby settlements.
- Rehabilitating and solving all the environmental issues at a site like Karabash will be difficult and the cost of carrying out rehabilitation to today's western standards means extensive rehabilitation is unlikely to happen. Ensuring particle emissions from the smelter are not impacting the health of local people should be the first priority at Karabash. The other priorities need assessing via the level of hazard they pose to local people and the potential risk of exposure to these hazards.

Understanding and reducing the carbon footprint of the mining industry

The carbon footprint study was conducted by literature review, interviews and correspondence with mining companies and a case study of the plans for the gold mine at Rosia Montana. The study showed that mining is a major user of energy, the industry has been calculated to use between 7 and 10% of the World's energy supply. Energy use is a major cost to the mining industry. For example, about 35% of the cost of copper production is the energy that is required. Besides energy, other contributors to the carbon footprint (via various greenhouse gas emissions) include explosives used in mining and acids used in extraction.

Based on the research in this sub-task, the current best practice in reducing carbon footprint was divided into three categories:

1) Energy demand reduction procedures and use of energy efficient technologies include simple measures such as from careful driving, roadway maintenance and simple power systems management measures that all mines can implement. However, large investment is required for measures such as in pit crushing and conveying and trolley assist to reduce haulage energy use and these are usually only suitable for large and deep open cast mines. There are also a range of measures suitable for underground mining, such as use of coal bed methane to generate energy, and research is taking place on these.

2) Use of low carbon energies, either in a national or local context. We found that all of the large multinational mining companies are carrying out projects using renewable or lower carbon energy (Table 1). Mining companies can work with the national power suppliers to improve use of low carbon energy. An example is the installation of a wind far in Chile. The national grid solution mentioned most often was hydropower but only the large multinationals are likely to influence these solutions. Use of renewable energy on mine sites to give direct power to the mine is increasing but still uncommon. It is difficult to satisfy the large and constant power demands of a mining operation with renewable energy. Use of biodiesel has the advantage of lower particulate emissions for underground operations as well as lower carbon emissions. We also found that some mines are maintaining the use fossil fuel but changing to natural gas power because this reduces their carbon footprint.

Table - Use of low carbon energy by mining companies

Company	Wind	Solar	Hydro	Biofuel	Geothermal	Natural gas	Trolley Assist	Reforestation
Barrick	X	X	X	X	X	X	X	X
Anglo	X	X	X	X		X		X
BHP		X	X	X		X		X
RioTinto	X	X	X	X		X	X	X
Goldcorp		X	X	X	X	X		
Teck			X			X		X
Newmont		X	X	X		X	X	X
Xstrata		X	X	X		X		X
Gold Fields	X	X		X				X
Vale			X	X		X		X

3) Offsetting carbon emissions either by reforestation or carbon trading is the third main way of reducing carbon footprint. In many situations, especially in the developing world where energy generating capability is limited, this form of carbon footprint reduction is inferior to energy saving measures. Planting trees can however be attractive and is widely adopted. It can require very large tree-planting programs. For example, at Rosia Montana it was calculated that planting 8000 hectares of forest would make the project carbon

neutral in 17 years. However, the mining company has committed to just 1000 hectares of reforestation in the local area and this will require some 39 years to achieve carbon neutrality, assuming Romania changes its current energy generation mix to meet EU targets on greenhouse gas emissions. There is no reason for reforestation to be confined to the local area and an offset could be achieved by planting anywhere in the world. International emissions trading of carbon credits are also a possible way to offset carbon emissions.

The results of the socioeconomic and carbon footprint studies link to the technical part of the program in:

- Making the study comprehensive by considering social factors and greenhouse gases as environmental pollution that cannot be directly measured by earth observation techniques;
- Providing information about people's concerns and how they prefer to receive information on environmental issues connected to mining activity which could be used in designing applications for the research outcomes of the project.

WP4 S&T results

In WP4 the basis for IMPACTMIN tools development was to be laid by generating a scientific knowledge pool of methods derived from mineral resources exploration methods, satellite EO-based environmental monitoring techniques and by 'translating' research results from other field of science with a possible applicability in ImpactMin. Additionally, preparatory work for demo-site implementation (in WP6 and WP7) was performed.

Reports:

D4.1 Report on the limitations and potentials of satellite EO data
D 4.2 Report on the compliance with relevant GEO tasks addressed by WP 4
D.4.3 Satellite mission planning for the demo sites

Activities and results

Assessment of environmental and surface variables through direct observation

The conducted literature study revealed a number of environmental variables, soil and surface variables, associated with mineral mining activities, which are to some extent detectable with satellite earth observation data. Variables (or impacts) were considered the effects on natural resources and on the components, structures and functioning of affected ecosystems. The variables were separated into direct and indirect variables. Direct variables meant the direct and predictable effects of mineral mining operations themselves, occurring at the same time and place. The considered "indirect variables" were defined as caused by mineral mining operations, but occur later in time or farther removed in distance.

The following direct variables were considered:

- Minerals
- Acid mine drainage and ferruginous materials
- Atmospheric pollution and windblown particles
- Temperature increment due to (underground) coal fires

The following indirect variables were considered:

- Land use and land cover change
- Vegetation stress
- Contaminated surface waters: sediment load and metal contamination
- Changes in soil moisture and groundwater environment
- Subsidence

After the identification of the basic environmental parameters the next step were to review the sensor properties and determine their potential is assessing the above listed environmental phenomena. In general as conclusion of the potentials and limitations, the work showed that satellite remote sensing can be successfully used for monitoring different variables associated with the environmental impact of mineral mining (based on e.g. sensor properties), although the same limitations arose: limited spatial resolution and/or limited spectral resolution of satellite imagery.

Knowledge-pool of verifiable examples of successful satellite EO methods, tools and algorithms

In this sub-task the existing tools and methods for the monitoring of mining impacts were compiled in a way, that the partners took into account the sensor properties, limitations and possibilities, advantages and disadvantages and finally, the potential of satellite remote sensing for mineral resources exploitation monitoring and the applicability and limitations of satellite remote sensing was described.

Concerning the monitoring of *direct environmental variables* related to mineral mining, the following conclusions can be drawn:

- Most high spatial resolution sensors lack the spectral resolution for successful **mineral mapping**. Lower spatial resolution sensors as Landsat or ASTER are widely used and have proven to be useful for mineral mapping at regional scale, although in case of Landsat, only broad groups of minerals can be identified. The SWIR bands of the ASTER sensor are a great benefit, allowing the identification of individual minerals and gradual changes. Unfortunately, since April 2008 there are no good observations in the SWIR range, because the detector saturates (ASTER Science Office, 2009).Theoretically, the Hyperion sensor would be of great use for regional mineral mapping, but the low signal to noise ratio is a large limitation.
- Although the spectral resolution of Landsat and – in particular – ASTER theoretically can be used to discriminate between different minerals related to **acid mine drainage**, the low spatial resolution will complicate the mapping of individual minerals or gradients of acid mine drainage. Worldview-2 might be used for the mapping of individual minerals (in particular iron oxides/hydroxides), since the spatial resolution is superior and Worldview-2 has 8 bands, although only in the VNIR spectral range.
- Large scale **atmospheric pollution** has been monitored using MODIS imagery, which has a high spectral but low spatial resolution, and using ASTER or even Landsat imagery (e.g. for monitoring urban air quality). Most studies however focus on the secondary effects from atmospheric pollution (land cover change and vegetation stress). Hyperion imagery can be used to study mineralogy of particulates in windblown dust. Nevertheless, the applicability of satellite remote sensing for monitoring atmospheric pollution depends on the severity and the spatial scale of the event.
- Primary factors in the applicability of satellite remote sensing for the detection of temperature increment due to **underground coal fires** depends on the background temperature, the quality of the remote sensing data, and the significance of the coal fires. Thermal infrared bands of Landsat, ASTER and even NOAA-AVHRR imagery were successfully used in large scale underground coal fires in China, Australia and India. For small scale events, the size of an individual fire will be smaller than the IFOV of the satellite, but sub-pixel detection might be possible, depending on the surrounding background.

Concerning the monitoring of *indirect environmental variables* related to mineral mining, the following conclusions could be drawn:

- For successful monitoring for the evaluation of **land use and land cover change** related to mineral mining and their dynamics, observations with frequent temporal coverage over a longer period of time are required. Landsat imagery is widely used for monitoring conversions from natural vegetation to surface mines, and afterwards to secondary vegetation after reclamation. However, the extent of land use and land cover change is often larger than the mine itself. Vegetation indices or other transformations are frequently used. Also time series of low resolution imagery (e.g. NOAA-AVHRR) have been used to monitor large scale land use and land cover change induced by mineral mining.

- Similarly, vegetation indices are used to monitor mining induced **vegetation stress**. Depending on the scale of the impact, high spatial resolution QuickBird or IKONOS, medium resolution Landsat or ASTER, or low resolution MODIS or NOAA-AVHRR is applied. Hyperspectral imagery from Hyperion facilitates a more detailed study of pigment concentration changes.
- Although the spectral and spatial resolution of satellite remote sensing systems does not allow for the assessment of **surface water quality** parameters individually (chlorophyll, suspended sediment and dissolved organic carbon), satellite imagery can be successful in monitoring dynamics of water clarity and for example dynamics of sediment loads, related with mineral mining.
- Satellite imagery can be used to detect drainage and landforms that act as direct indicators of **ground water** occurrences. Both multidate VNIR, TIR and radar observations are used to monitor moisture content of the soil. Surface features are analyzed in terms of geomorphology, relative groundwater depths and vegetation patterns, not by quantitatively relating soil moisture to reflectivity, which is too variable in space and time.
- Using multiple synthetic aperture radar observations, differential radar interferometry can measure surface deformation and **subsidence** to high degree of accuracy over large spatial extents.

The Report on the limitations and potentials of satellite EO data summarizes the results of the work of the above mentioned sub-tasks. Methods from different areas of environmental monitoring, other than mineral resources exploitation, were also taken into account, and they have been translated for applicability in monitoring mining impacts. Additionally, the proper analysis software, algorithms and procedures needed to extract useful information from various datasets, in order to optimize the efficiency of the analytical procedures have been discussed by the report.

The applicability and limitations of satellite remote sensing is summarized by the below table:

Table 3-7 Applicability of satellite imaging systems for the monitoring of mining impacts

	Optical sensors																					
	IKONOS	RapidEye	SPOT HRV	QuickBird	GeoEye-1	Worldview-2	Landsat 1-3	Landsat 4-5,7	ALI	ASTER	Hyperion	CHRIS	*PRISMA*	*HyspIRI*	*EnMAP*	MODIS	Spot-VGT	MERIS	SEVIRI	NOAA-AVHRR	**Thermal sensors**	**Radar sensors**
Sensor parameters																						
Spatial resolution	***	***	***	***	***	***	**	**	**	**	**	**	**	**	**	*	*	*	*	*		
Spectral resolution	*	*	*(*)	*	*	**	**	**	**	**	***	***	***	***	***	***	*	***	***	*		
Temporal resolution	**	**?	*	**	**	**	*	*	*	*	*	**	*?	*	**	**	**	**	***	***		
Length of time series	*	*	*	*	*	*	**	**	***	***	**	*				***	***	***	***	***		
Cost of acquisition	*	*	*	*	*	*	***	***	***	**	*					***	***	***	***	***		
Applicability																						
Direct variables																						
Minerals			(*)			*		*	*	**	*	**	**	**	**							
Acid mine drainage and ferruginous materials	*	*	*	*	*	***		*	*	**	*	*		**	**							
Atmospheric pollution and windblown particles	*	*	*	*	*	**	*	**	**	**	*	*		**	**							
Temperature increment due to (underground) coal fires								**		**				**							*	
Indirect variables																						
Land use and land cover change	***	**	***	***	***	***	**	**	**	**	**	**	**	**	**		*			*		
Vegetation stress	*	*	*	*	*	**	*	*	*	**	**	**	**	**	**		*			*		
Contaminated surface waters: sediment load and metal contamination	*	*	*	*	*	**	*	*	*	**	*	*	**	**	**							
Changes in soil moisture and groundwater environment	*	*	*	*	**	*	*	*	**	*	*	*	*	*	*	*	*	*	*	*	**	**
Subsidence										*												**

***: very good, ** fair, *: limited

Preparatory work for demo-site implementation

The relevant parameters related to mining impact were identified by this sub-task and all available information was gathered in order to quantify the impacts of mining related activities. In many cases, previous researches only give an indication of the seriousness of the ongoing processes. Nevertheless, for each demo-site several core topics for satellite image processing were identified. The satellite mission planning contains a concise description of each demo-site that are considered in the this Work Package, and where satellite data was possible to be collected, processed and analyzed. For each demo-site, an analysis flow sheet was prepared, which summarizes data acquisition, data processing and derived products. These analysis flow sheets are the core of this satellite mission planning, and provided a general guideline for image acquisition, processing and analysis in Work Package 6. For each demo-site, the flow-sheet is described in detail. The below figure illustrate an example flow sheet for Mostar site.

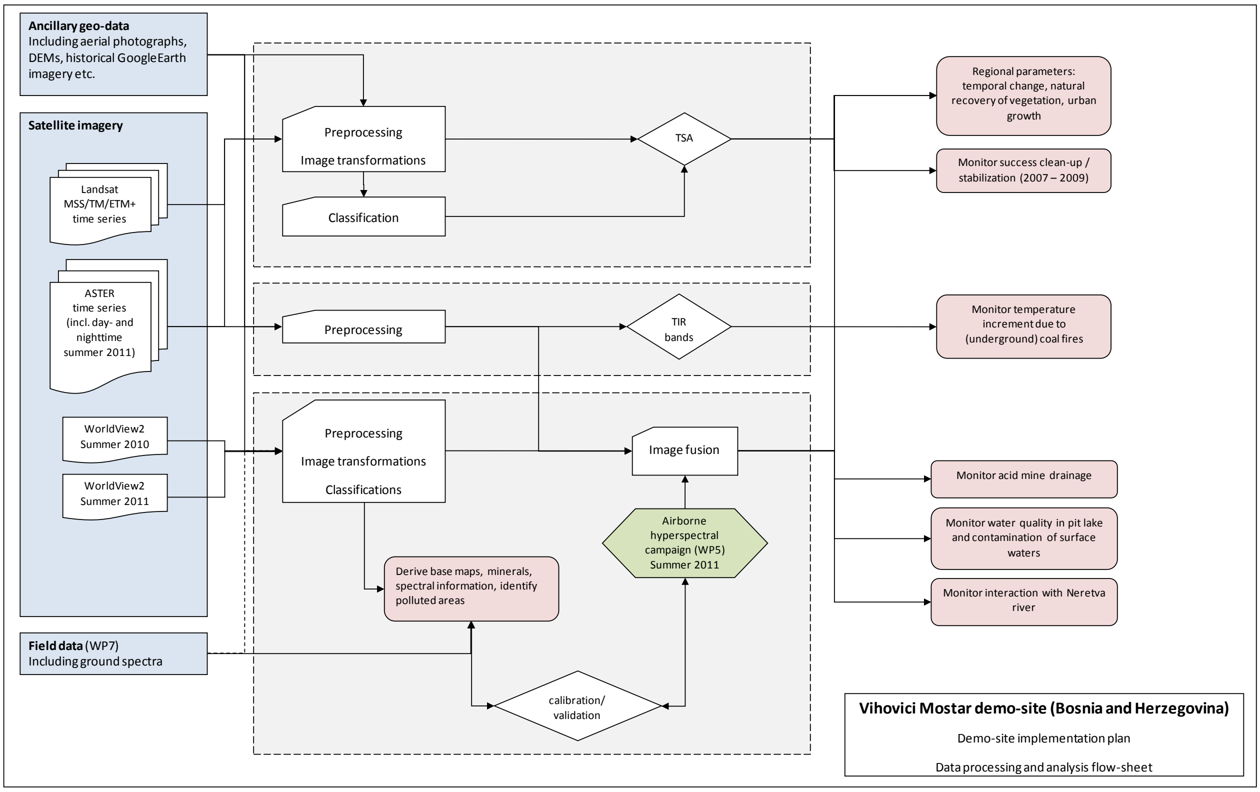


Figure – Example of an analysis flow sheet (source: Deliverable 4.3)

The conclusions of the satellite mission planning are summarized as follows:

- There are only a limited number of satellite sensors that provide imagery for this project: NOAA-AVHRR, SPOT-Vegetation, the different Landsat sensors, ASTER, SPOT and WorldView-2.
- The low spatial resolution sensors (NOAA-AVHRR and SPOT-VGT) will be used to monitor general changes in vegetation in a wide area around the demo-sites where largest environmental impact is expected (mainly Karabash and Mednogorsk).
- Time series of medium spatial resolution sensors (Landsat and ASTER) will also be used to monitor regional parameters and temporal changes. For this time series analysis it will be extremely necessary to standardize the data.

- Pre-processing of images is important in order to create geometric and spectral consistency.
- High resolution imagery (SPOT-5, WorldView-2) will be used to monitor specific environmental problems at each demo-site: detailed base maps (all demo-sites), minerals or mineral groups (Karabash and Mednogorsk), acid mine drainage and surface water pollution (Mostar, Rosia Montana, Karabash and Mednogorsk), vegetation stress (Rosia Montana, Karabash and Mednogorsk).
- For Mostar and Rosia Montana, the interaction with a hyperspectral airborne campaign will provide many possibilities for calibration and validation.
- For Mostar, but Rosia Montana, where both satellite and airborne imagery will be available, image fusion of satellite and airborne imagery becomes possible and will be considered a good experimental opportunity.

NOTE: When the satellite mission planning report was compiled (2010), WorldView-2 was the first satellite that offers 8 spectral bands at high spatial resolution.

Compliance with existing standards, software environment by tackling relevant GEO tasks

The major objective of this sub-task was to establish procedures that creates the possibility for bringing all information into a digital environment (GIS), and that all types and all source of geodata can be handled interestedly. In general for the ImpactMin project the standard data formats and procedures (ISO-compliant) were high priority in order to establish a systematic and repeatable observation and monitoring programme.

The result of this sub-task is the “Report on the compliance with relevant GEO tasks”. This report contains a description of GEO and GEOSS and how ImpactMin can contribute to and benefit and actually frame its activities according to this international initiative. An overview of existing standards, directives and guidelines were also included.

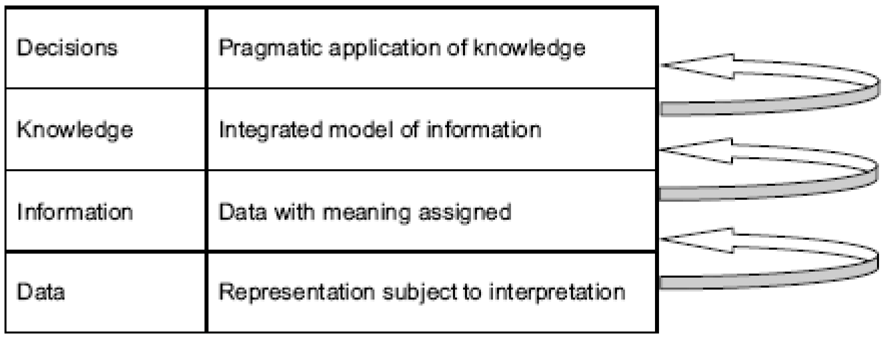


Figure - ISO 19101-2:2008 Reference model – Part 2: Imagery

The report that was based on this task contains:

- compliance assessment with existing standards and practices (an example, based on the INSPIRE Metadata Regulation (2008)
- recommendations for the ImpactMin project, based on GEO(SS), INSPIRE and QA4EO guidelines for data formats, coordinate system, metadata, data quality documentation etc.

These recommendations have been taken into account by Work Package 6 and 7.

WP5 S&T results

In WP5 the emphasis was based mainly on the airborne environmental monitoring techniques and their in-situ sampling/ground-truthing based on the adaptation of results and methods from other field of science with a possible applicability in ImpactMin. On the other hand the information that the parallel work package (WP4) was producing e.g. the generation of a scientific knowledge pool of methods derived from mineral resource exploration and exploitation method was influencing the process of this Work Package.

Reports:

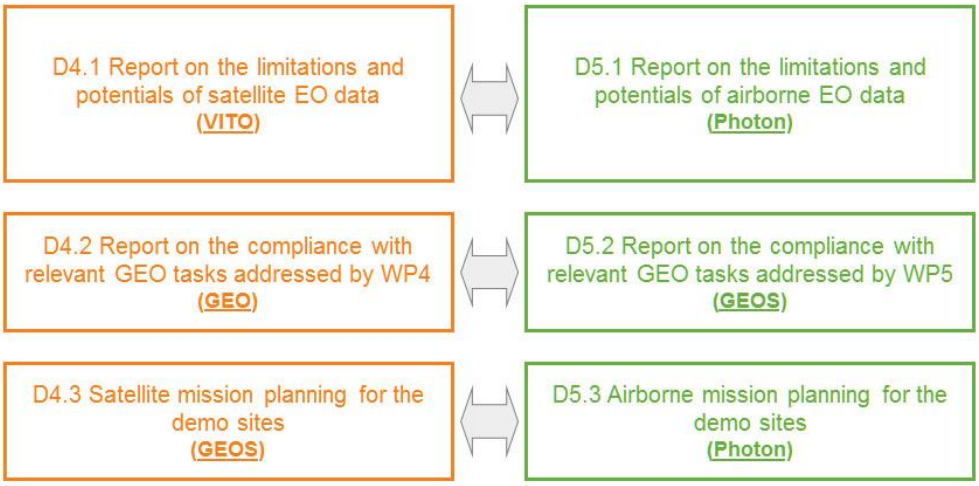
D5.1 Report on the limitations and potentials of airborne EO data
D5.2 Report on the compliance with relevant GEO tasks addressed by WP 5
D.5.3 Aerial mission planning for the demo sites

Activities and results

Evaluation of the usability and feasibility of airborne systems

Similar to the parallel work package (WP4) in this sub-task the environmental variables associated with mining activities and detectable with airborne remote-sensing and geophysical data were examined and identified with attention given to the general observables. Furthermore, the WP had outlined certain sensor properties, advantages and disadvantages, including also limitations and different methodological approaches.

Figure – Correlation of WP4 and WP5 and associated deliverables



Existing tools and methods for the monitoring of target detection and mining impacts were identified and methods from different areas of environmental monitoring, were reviewed and, where possible, translated/adapted for applicability in monitoring mining impacts. Finally, the adequate analysis approaches, algorithms and procedures needed to extract useful information from various datasets, in order to optimize the efficiency of the analytical procedures, were identified, evaluated and suggested for further work.

This Work package dealt with the following airborne remote sensing tools for environmental monitoring:

- Visible electro-optical devices
- Hyperspectral sensors
- Airborne radiometric assets

In order to compile a knowledge pool of existing methods and approaches for the monitoring of mining impacts, the involved partners had evaluated the potential of novel airborne remote sensing platform and the feasibility of assessment of different environmental variables associated with mining activities, on both microscopic (spectral mineralogy) and macroscopic (regional environmental impact) scale. The role of airborne spectroscopic remote sensing was evaluated as it fits the niche between the regional satellite assessment and ground point-sampling.

The definition of environmental direct and indirect variables associated with mining activities that are suitable to record by airborne remote sensing devices (list above) were described in detail; a short summary is provided below.

Table - Summary of the relevant direct and indirect variables possible to detect with airborne remote sensing

Observable	Type	Method	Direct	Indirect
Gas, aerosol, dust, smoke	Atmospheric	Hyperspectral	X	
Water turbidity, clarity	Hydrologic	Hyperspectral	X	
Surface pollutants	Material	Hyperspectral and Gamma Ray	X	
Plant health, biodiverstiy	Biosphere	Hyperspectral		X
Heavy metal pollution	Material	Hyperspectral		X
Acid mine drainage	Material	Hyperspectral	X	
Organic pollution	Hydro-Biosphere	Hyperspectral, Gamma Ray		X
Land Stability	Geology	Hyperspectral		X

An in-depth overview of each sensing system and their limitations, advantages and disadvantages have been presented throughout the report “Limitation and potentials of airborne EO data” and variety of disciplines ranging from vegetation studies, over minerals to atmospheric and water studies. A thorough literature study and scientific-communication with other experts in the field and within the consortium were performed in order to get a view on previous use of the different sensors for environmental impact monitoring of mining.

Preparatory work for demo-site implementation

The site assessment was somewhat similar in approach: moving from general information, established through background research and space-borne remote sensing studies and moving towards detailed, tasked airborne and ground-based sampling approaches. The overall interest was to present an integrated chain of regional-to-local assessment of variables and observables associated with past, current and possibly future mining operations in various environments.

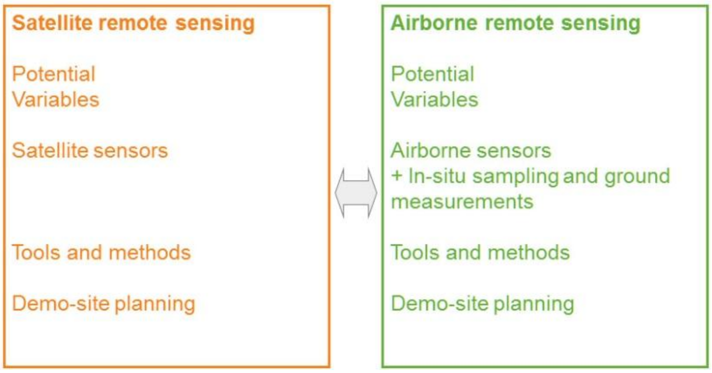


Figure - Correlation between satellite and airborne planning and execution, WP4 and WP5 (Photon)

The study sites, presented in the resulting report “Aerial mission planning for the demo sites”, were offering ideal testing ground in appraising capabilities of an integrated airborne collection approach with the other types of data, because of their environmental diversity, presence of particular signatures characteristic of mineral exploitation and different strategies required or available to collect the necessary information.

The above mentioned report (Deliverable 5.3) summarized the results and put forth recommendations for demo-site implementation discussed in D5.1 and conclusions from the Airborne Operation Workshop held in Split in September 2010. The report also correlated with information from the scope of work performed under the respective task in Work Package 4.

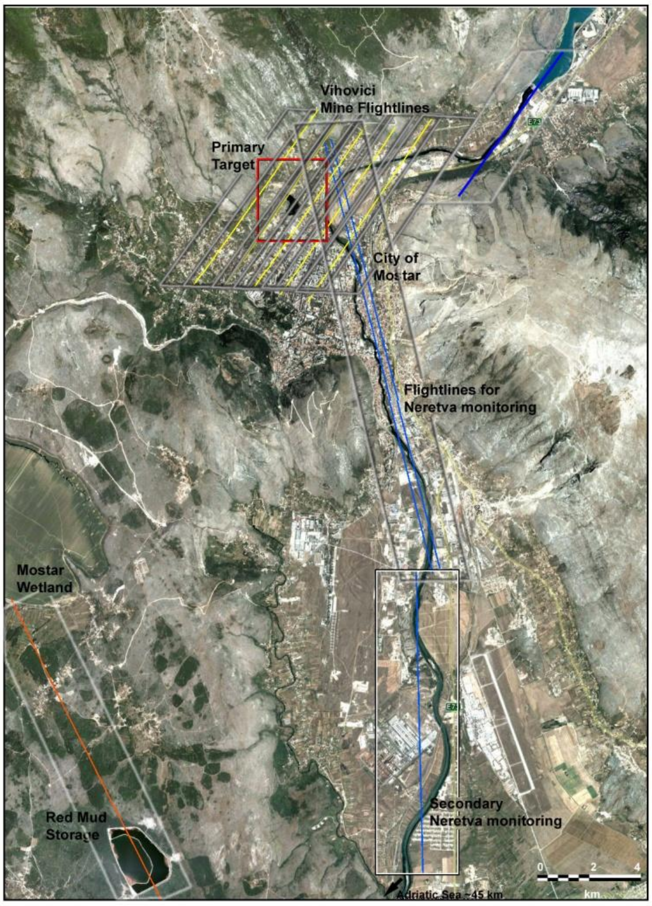


Figure – Approved flight plan over Mostar Valley with the approximate footprint of the imagery acquired with the hyperspectral sensor.

The tactical nature of the data collections obviously made this segment of the ImpactMin proposal probably the riskiest and most exposed to various changing conditions: from weather to legal challenges of operating and collecting data in an active and at times contentious environment. The negative properties of the airborne remote sensing were defined as:

- main disadvantage of the approach was identified in the requirements for nearly ideal acquisition conditions: clear weather and abundant sunlight for hyperspectral
- secondary disadvantage that was identified the relatively high cost of mobilization and the amount of data generated that requires considerable technical proficiency in analysis and interpretation.

The major positive attribute of using airborne EO data for the environment monitoring if ImpactMin demo sites were:

- The ability to resolve the subtle indicators and clues is directly proportional to the quality of data collected, but also the premises and parameters determined in data acquisition and analysis
- The sheer quantity and redundancy of hyperspectral (HSI) and the field calibration data makes it is possible to increase the level of confidence in target unmixing and detection.

Therefore, the airborne component meant to fill the important niche (in the Mostar, Krisitneberg and Rosia Montana case studies) situated between in-situ measurements and space-borne sensing.

There were also important conclusions derived already at this early stage of the project, concerning the legal and logistical framework of airborne remote sensing. It was recognized that the legal code in some of the target countries, even though in process of change, has still retained some of the past provisions requiring numerous approvals, licensing and notification requirements from the pertinent ministries (e.g. Defense, Internal Affairs) in order for the surveys to take place.

In concluding some of the challenges of the airborne EO data collections that were identified during WP5 there is a list here about issues tackled, and to be tackled in future projects with similar research profile:

- The value of new technology and sensing must be explained in great details to beneficiaries and shareholders, because of lack of knowledge and fear of airborne reconnaissance (high resolution data collection)
- The stigma associated with remote data collection and utilization must be broken and institutional mistrust mitigated by allowing the users/decision-makers unhindered and transparent access to all data collected over particular territory
- The premises/concepts of open-sky and GEOSS must be expanded and reinforced in the emerging states of the Western Balkans and engaging all decision-making elements in the society in progressive development and facilitating the new venues of data collection and surveying
- Expanding the capabilities of low-cost and on-demand airborne remote sensing
- Expanding the capabilities of inter-disciplinary research in the elements of spectroscopy
- Making powerful analysis and visualization software available to potential users to take full advantage of the new datasets.

WP6 S&T results

The main objectives of this Work Package were to develop, validate and deploy harmonised methods for the assessment and monitoring of environmental impacts from mining operations. In doing this the WP activities had to follow the technical recommendations and used the knowledge pool resulted by WP4 and WP5. Also site specific and stakeholder specific aspects needed to be taken into account. It is important to note, that two Work Packages (WP6 and WP7 - Demonstration) have begun on the 13th month of the Project. These two WPs are highly interlinked and continued running parallel until the end of the project.

Reports:

D 6.1 Compendium of methods and tools for the monitoring the environmental impacts from mining and mineral exploitation activities
D 6.2 Full-scale operational UAV-system for Aerial EO-based environmental monitoring and assessment at mining sites
D.6.3 Report on the contribution to relevant GEO tasks and GEOSS components

Activities and results

Acquisition, processing and analysis of Satellite data

For all project areas the Consortium acquired all archived medium resolution optical imagery of sufficient quality in order to be able to generate time-series analysis for change detection. High-resolution imagery (Spot, Worldview2, Geoeye) was acquired for all project areas. All imagery was orthorectified and prepared for further analysis. High resolution imagery was used as a basis for planning fieldwork in the various project areas. Image data stored in the appropriate UTM-WGS84 coordinate system, in Geotiff and/or ENVI-format.

- Landsat- (from Geocover archives – http://landsat.gsfc.nasa.gov/data/reduced.html) and
- Aster- (from ERSDAC archives – http://imsweb.aster.ersdac.or.jp/ims/html/MainMenu/MainMenu.html)

The following list shows the detailed activities and technical work performed for this sub-task:

- Acquisition and spatial and spectral analysis of time series Landsat imagery (1987-2011) for the Urals Project areas
- Acquisition and spatial and spectral analysis of High-resolution (Geo-Eye and WV2) imagery for the Urals project areas
- Acquisition and spatial and spectral analysis of Landsat, Aster and high-resolution (WV2) imagery for the Mostar project area
- Acquisition and spatial and spectral analysis Landsat, Aster and of time-series of high-resolution (WV2) imagery (2011-2012) for the Rosia Montana project area
- A time series of 10-daily NDVI and fAPAR images derived from SPOT-Vegetation (S10 January 1999 to December 2011 at 1km² resolution, http://www.vgt.vito.be/) was analyzed for the Karabash and Mednogorsk demo sites
- Methodology development for normalisation of Landsat time series

Acquisition, processing and analysis of airborne data

KRISTINEBERG:

- The aerial survey at the Kristineberg area (including the downstream localities) was performed 14 July 2011 using the Smartplanes AB UAS system.)
- The generated red–green–blue (RGB) images were post-processed by GerMAP GmbH (Welzheim, Germany)
- The resulting orthoimages had a spatial resolution of 5 cm and were georeferenced to the Swedish national grid using ground control points identified in orthophotographs from the Swedish Land Survey. For fine adjustment, we used the georeferencing tool in the ArcGIS software for each location, 15–20 control points were used to reduce the root mean square error to <10 cm. The control points were measured on site using a carrier-phase enhancement global positioning system (CPGPS) with a spatial error of <5 cm
- Vegetation was mapped in the ArcGIS software and was based on the high-resolution orthoimages, the field data on species composition and cover in the sample plots and local knowledge derived from field visits
- Mapping was performed at a scale of 1:100 with a minimum mapping unit of 0.4 m2. Image interpretation was entirely visual. At each location, a 320-m river stretch was mapped.

MOSTAR:

- Airborne hyperspectral overflight using AISA Eagle sensor at approximately 5nm spectral and 1m spatial resolution encompassing most of the River Neretva, Vihovici Mine, City of Mostar, aluminum refining plant and red mud storage site
- UAV overflight at approximately 5 cm ground resolution, targeting the localities of Vihovici mine and Neretva river
- Processing of Smartplanes UAV-data and integration with ground and satellite data
- Tasking, Collection, Processing, Exploitation and Dissemination (TCPED) of acquired airborne data inclusive of (June – December 2011):
- Corrections and calibration of acquired data (July – August 2011)
- Geological, geotechnical and geobotanical analyses of sites in Mostar Valley – correlation with known/accepted USGS/NASA/ESA/VITO standards for valid hyperspectral data (October 2011)
- Ground-truthing and validation campaigns in Mostar areas (November 2011)
- Quality control of airborne hyperspectral EAGLE images of Mostar: a second empirical line atmospheric correction using also a dark reference target (water) was recommended to Photon
- Application of relation between field spectral measurements and water quality parameters of Vihovici and Neretva river (Mostar) determined from in-situ measurements to EAGLE airborne reflectance images
- Validation of water quality maps of Vihovici and Neretva with in-situ water quality parameters
- Delivery of water quality maps (in GEOTIFF) and metadata of Vihovici and Neretva based on EAGLE hyperspectral airborne images
- Spatial unmixing based fusion of SmartPlanes UAS (RGB, 5 cm spatial resolution) images acquired by GEOSENSE and WorldView-2 images (8 spectral bands and 2 m spatial resolution) resulting in images of 20 cm spatial resolution (after spatial degradation) and 8 spectral bands allowing a more detailed interpretation of the vegetation health status

ROSIA MONTANA:

- Planning and execution of 2012 Manned low-altitude Hyperspectral survey, in cooperation with Geonardo, Vito and UBB
- Planning and execution of 2012 Smartplanes Unmanned aircraft surveys
- Processing of the Smartplanes UAV-data and integration with ground and satellite data
- Geometric quality assessment of airborne hyperspectral EAGLE images acquired in August 2012
- Accurate geometric correction and mosaicing of hyperspectral image strips
- Processing and analysis of Hyperspectral imagery for classification of vegetation and soils
- Detailed investigation of the limitations of spatial resolution of the hyperspectral imagery, Worldview2-imagery and Smartplanes UAV imagery
- Investigation and confirmation of compliance of SPECIM EAGLE and EAGLET (i.e. lightweight) hyperspectral sensor/data specifications with VITO's Central Data Processing Center requirements
- Spectral and radiometric quality assessment of airborne hyperspectral EAGLE images acquired in Rosia Montana in August 2012
- Testing optimal vegetation stress indices (e.g. NDLI) determined from leaf spectral measurements acquired in June 2012 and August 2012 to airborne hyperspectral EAGLE images acquired in August 2012 of a polluted and non-polluted region in Rosia Montana.

Collection, analysis and interpretation of ground data (methodology and logistical framework)

Data collection for geochemical and spectral investigation:

- For chemical analyses of riparian vegetation, representative samples of the two dominant plant species in each belt at each location were taken. For vegetation from the river channel, there were representative samples taken of the three dominant species at locations.
- Analysed variables included concentrations of Al, As, Ba, Ca, Cd, Cl, Co, Cr, Cu, Hg, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Ti, V, Zn, and tot-N
- Characterisation of rocks and soils by means of infrared spectroscopy, XRD, XRF: the sampling programme included mineralised areas, altered areas, unaltered areas, dumps, tailings etc for correlating this information directly with other ground data on one hand, and with the satellite data on the other.
- Water quality samples and ASD-measurements for pit lakes and on parts of the river (Neretva- Mostar)
- Stream and lake sediment sampling were carried out at specific sites to assess the extent of their contamination from acid rock/mine drainage from wastes, tailings and abandoned mine workings and effluents from the smelters and processing plants.
- Spectral analysis of leaves and pine needles was conducted along a number of profiles in order to determine the degree of vegetation stress
- Leave samples were collected from each spectral sample site for chemical analysis.
- A new lichen transplant program has already been implemented by the representatives of the Camborne School of Mines –University of Exeter

These trips and data acquisitions were directed towards to implement the recommendations of Deliverable 4.2. The particular items to be inspected were:

- Quality Control/Quality Assurance indicators (for EO data)
- Formulate descriptive information about calibration and validation and local parameters
- Terminology/definition
- Background/context/requirement
- Evaluation of performance.

The below table is an overview of the different tools and analysis methods that are mostly employed during the Project implementation.

Information on the Environment	Observed Environmental Media	Analysis	Tools
Biodiversity, Land use	Vegetation, surface objects	Spectral	Ground, Remote Sensing (RS)
Planning of operation, Land use change	Surface objects, vegetation	Spectral	Ground, RS
Status of Air	Air, Plant leaf/stress	Mineralogical, spectral	Ground, RS
Status of Waters	Water and sediments	Geochemical	Ground
Status of Soils (Waste)	Soils	Spectral, Geochemical	Ground, RS

In the ImpactMin project the tools means mostly “hardware” assets that consist of satellite “imagery systems” and the imagery itself, as well as airborne imaging systems and outputs. The actual imagery is the imaging sensor system output with well defined parameters (spectral, radiometric etc. resolution). Furthermore tools were the in-situ (ground based) measurement techniques such as spectrometry and well established field data - laboratory analyses. Methods were analysis activities that needed human resources and logic for interpreting EO data and process it to (geographic) information.

Novel tools and data integration tested and validated in the frame of Work Package 7 (next page). Here are some high point conclusions that can be summarized:

ImpactMin project presented a number of new tools and approaches for the collection and interpretation of information that allowed us to improve to our ability to monitor environmental impact in an efficient and cost-effective manner. Integrated analysis of data has demonstrated that traditional ground sampling methods, such as geochemistry, can be integrated with fast and cheap methods such as infrared spectroscopy, and by a variety of remote sensing techniques using optical sensors on UAV’s, manned aircraft and satellite.

New techniques such as lichen monitoring and infrared measurements of vegetation stress parameters were also suitable next to the conventional analytical tools to directly measure for instance responses of vegetation to airborne pollution. Detailed studies of the integration of ground data with ultra-high resolution UAV imagery, very low altitude and low altitude hyperspectral surveying, very high resolution optical satellite image and conventional Landsat imagery has been demonstrated as well as the complementary nature of these different datasets.

Outcomes of the ImpactMin project can form a basis for further research and innovation in the fields for integrated environmental impact analysis, hyperspectral and multispectral remote sensing, and the use of unmanned aircraft as a cost effective and flexible platform for new miniaturized sensors (image on the left WorldView2 satellite imagery overlaid with an ultrahigh resolution airborne optical imagery acquired by Unmanned Aerial Systems).

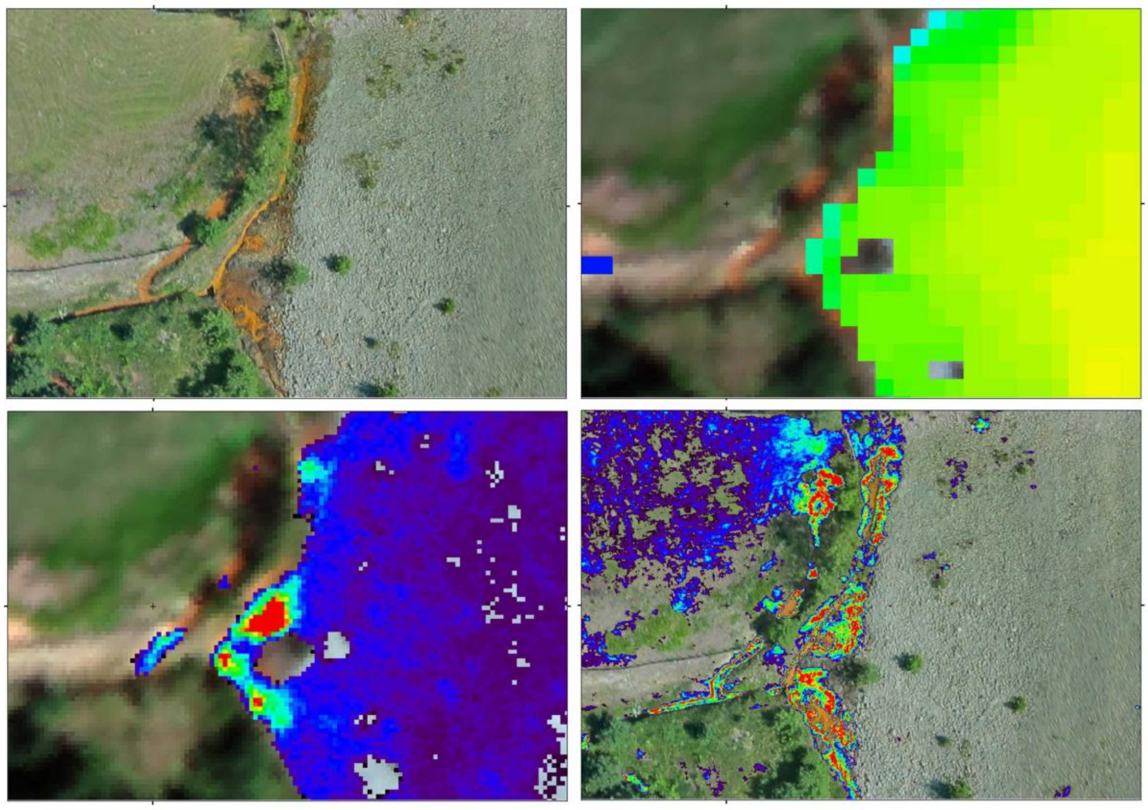


Illustration example for novel tools and methods - Comparison of Iron-oxide classification on the basis of WV2 and Hyperspectral imagery for an acid drainage outlet of the tailings dam. Top left: Smartplanes image; Top right: Classification of WV2-imagery; Bottom left: Hyperspectral classification; Bottom right: Smartplanes classification.

WP7 S&T results

Demonstration and calibration of the proposed tools and services have been successful over the course of WP 7. Work Package inputs (WP4/WP5 knowledge base and mission plans, WP6 methods and tools) were fully exploited during demo site implementations. The study areas that were selected for the Project were very diverse with respect to the nature and scale of the environmental impact. This diversity allowed us to explore the use of remote sensing technology under a wide variety of conditions, and to identify appropriate procedures for combining discrete field data and continuous remote sensing data in order to optimize the relation between efficiency of feature detection and cost of data acquisition and processing.

Major reports and deliverables:

D7.1 Report on the Kristineberg Case study investigations
D7.2 Report on the Mostar region Case study investigations
D 7.3 Report on the Rosia Montana Case study investigations
D 7.4 Report on the Chelyabinsk – Orenburg case study investigations
D7.5 Comparative case-study assessment – best practice tools and methods implementation

Activities and results

NOTE: This report only provides excerpts of the case study investigation deliverables, thus in all cases for further information, please refer to the detailed documentations that are downloadable from the ImpactMin website.

Kristineberg, Sweden

Kristineberg workflow (tools and methods used):

Aerial survey, data aquistion and analyis – Aerial surveys were perfomred withan ultra-light remotely controlled aircraft equipped with a digital camera with calibrated optics, autopilot and GPS, and a ground control station with mission planning and flight control software. Aerial mapping software was employed for automated on-site production of georeferenced high resolution image mosaics. Final orthoimages had a spatial resolution of 5 cm and were georeferenced and used in GIS for vegetation mapping.

Field survey, sampling and analysis - Field sampling was performed at the three localities L1, L2, and L3 downstream of Hornträsket and the mining area. At each locality, a 50 x 20 m area that stretched along Vormbäcken was sampled. Vegetation was sampled in five belts (I-V) parallel to the river bank that were 4 m wide. In each sample plot, the cover of the five species with the highest cover was recorded according to a four-graded scale. For chemical analyses of riparian vegetation there were representative samples taken from the two dominating plant species in each belt at each locality. To get representative samples per species and belt with a minimum weight of 50 g, we collected leaves of at least 20 different specimens distributed over the whole belt by tearing or cutting with a plastic knife. At each locality, samples for water chemistry were taken. Analysed variables included dissolved (<0.45 µm) concentrations of all elements analysed in vegetation, except of Ti and V. In addition, NH_4-N, NO_3-N, NO_2-N, and TOC as well as chlorophyll content, alkalinity, conductivity, pH, colour and absorbance (420 nm) were analysed.

Results and conclusions

Biomass assessments conducted by remote sensing using satellite images of varying spatial resolution (1–30 m) have successfully been applied to large-scale single-species stands in wetlands, and in assessing total wetland biomass. Applying such traditional remote sensing with satellite images to the riparian zones studied here, however, would overlook the high spatial variation in vegetation stands, biomass, and trace element uptake. The method presented is suited for a more accurate assessment in terms of vegetation class- and species-specific biomass and trace element contents. This allows for detailed modeling of nutrient and trace element cycling in the riparian zone and of interactions with the adjacent aquatic system.

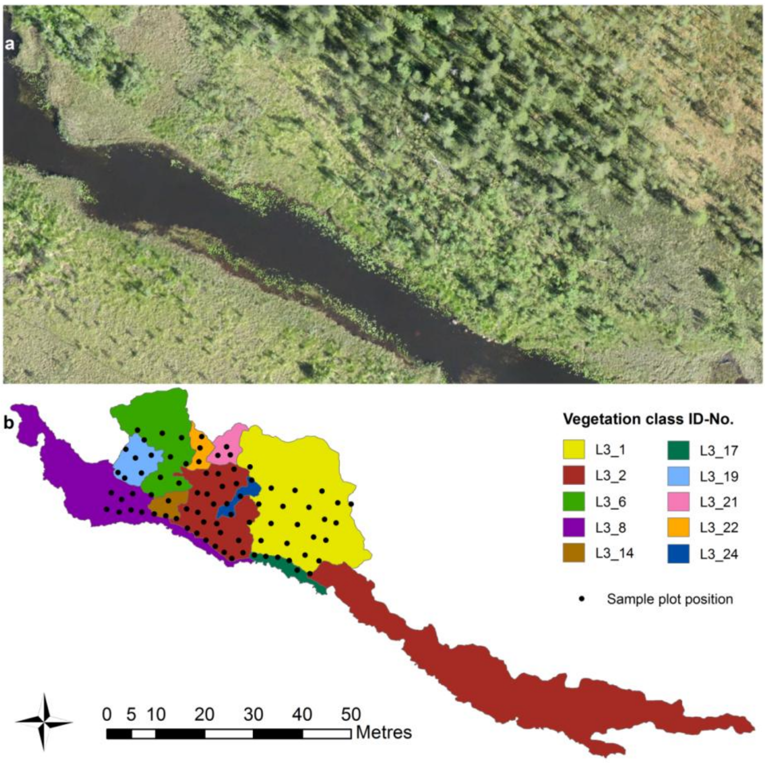


Figure - Core zone at location L3, a) orthoimage and b) vegetation map with sample plots

Mostar, Bosnia and Herzegovina

Mostar workflow (tools and methods used):

Aerial survey and furhter data aquistion and analysis - The AISA Eagle II^{tm} instrument used for the acquisition was calibrated by SpecIM. The instrumentation was bore-sighted upon the installation and INS calibrated and tested with GPS system. The survey was flown at an altitude of about 1100m AGL, which gave the average ground-instantaneous field of view (GIFOV) of about 1.02 m. A total of 20 flightlines were acquired during the mission, with some of the data being repeated, to ensure good target coverage and minimal glint from the water surface targets (pre-processing steps: raw data converted to radiance using SpecIM caligeo software, spec-cal parameters derived from LabSphere data, radiance to reflectance done with ATCOR using 3nm atmospheric model, ATCOR reflectance to Empirical Line reflectance using 1 dark (deep water), 1 bright (limestone gravel road) target and then improved using 16 other intermediate ground reflectances, orthogeorectification based on BH Geodetic survey mesh 1:25,000). The UAV overflight was undertaken to acquire high-resolution images of the Vihovici mine and Neretva River and assist in interpretation of targets with added detail. Five flights were carried out with the Smartplanes UAV to collect high resolution (5cm) aerial photographs of the open pit area and of the several sampling sites in the Neretva River. The stereo imagery collected for the open pit area was used to generate a Digital Surface model with a vertical precision better than 10 cm.

Field survey, sampling and analysis – Ground spectra (rocks) were taken with an ASD-terraspec full-range spectrometer, equipped with a contact probe. Four ground-teams took water samples at the time of the hyperspectral overflight at the river Neretva. A total of 40 water samples were collected and preserved during the field campaign. The samples were immediately transported to the Federal Institute of Public Health of Bosnia and Herzegovina where the water chemistry was analyzed for chlorophyll, suspended material, nitrites, nitrates, total Nitrogen and Phosphorus, Cadmium, Lead, Iron and total PAH and PCB. The water-leaving reflectance was measured with an ASD FieldSpec Pro FR spectroradiometer. The ASD spectroradiometer measures the reflected light in the the Visible/Near Infrared (VNIR, 350- 1050 nm) and the Short-Wave Infrared (SWIR, 900 – 2500 nm) portion of the electromagnetic spectrum. The downwelling irradiance above the surface (Ed(0+)) was measured using an almost 100% reflecting Spectralon reference panel (Analytical Spectral Devices, Inc.). Then, the total upwelling radiance from the water (Lu(a)) (i.e. from the water and from the air-water interface) was measured by pointing the sensor at the water surface at 40° from nadir, maintaining an azimuth of 90° or 135° from the solar plane, depending on the boat orientation with respect to the sun. Downwelling sky radiance (Lsky(a)) was measured at a zenith angle of 40° to account for the skylight reflection.

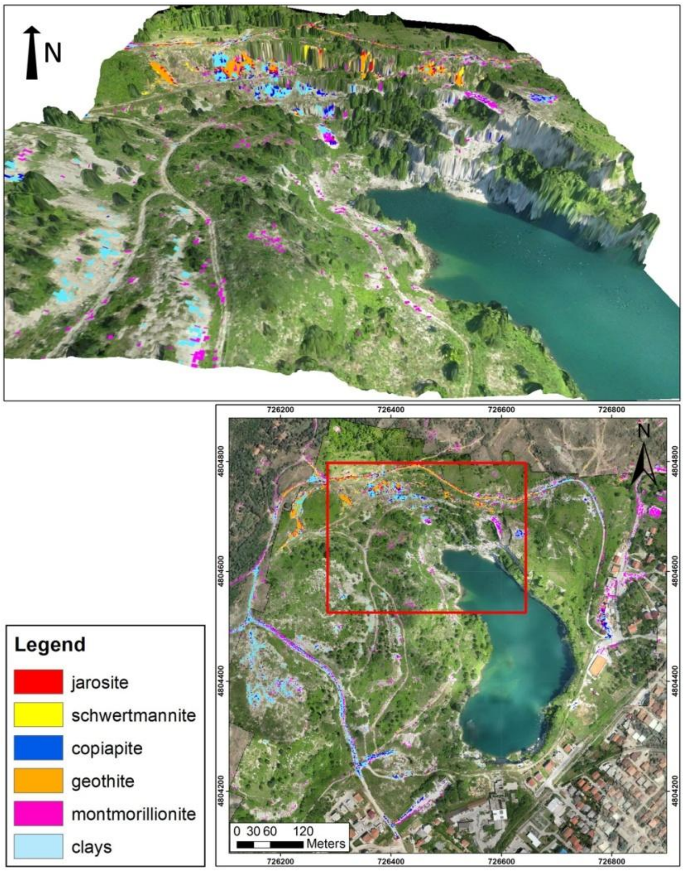


Figure - Mineral map and topographic model generated from UAS imagery showing surface mineral concentrations: most important are significant clusters of sulfate minerals (e.g. jarosite) on the northern end.

Results and conclusions

The hyperspectral survey has been successful in detecting iron oxide, hydroxide and sulfate minerals that may have a negative effect on the environment. It was determined that hyperspectral data can detect the subtle changes in surface mineralogy as a result of coal-seam fires. Fe-hydroxides, associated with bauxite/alumina refining at the red mud Storage Lagoon suggest drying and dispersal beyond the containment area and warrant closer inspection, particularly for the risk of heavy metal toxicity and naturally-occurring radionuclides. These may have been present in the ores used, as suggested from the different spectral reflectance phenomena. There were suitable algorithm modification performed to the map of Total Suspended Matter (TSM), chlorophyll (CHL-a) and select nutrients based on remote sensing imagery. For TSM, a highest correlation is found for wavelengths 550 nm to 600 nm. For CHL-a these regions are from 480 nm to 575 nm and around 675 nm. These are highly correlated with the regions found for nitrates and total nitrogen, as these nutrients induce the growth of phytoplankton, and thus CHL-a, in the water. A majority of the observed effects from the increased concentrations of chlorophyll/nutrients in the

Neretva river occurs within the narrow urban corridor, with the city of Mostar being the largest single polluter of this type.

Rosia Montana, Romania

Rosia Montana workflow (tools and methods used):

Aerial survey and furhter data aquistion and analysis - The hyperspectral survey was flown at an altitude of approximately 750 m above ground, resulting in imagery with approximately 50 cm resolution. 19 lines were flown with a total line length of approximately 140 km. The data were geometrically corrected and orthorectified by the University of Helsinki, This was initially based on the use of the GPS/IMU flight data, and a detailed photogrammetric Digital Elevation Model supplied by RMGC (pre-processing: two distinct atmospheric correction algorithms were tested, i.e. ATCOR 4 and FODIS) and the sub-contractor provided level-2, geometric and atmospheric corrected imagery. Two areas were flown with the Smartplanes UAV. In order to obtain an image resolution of 4-5 cm, it was need to fly between 125-150 m above ground, whereas a survey altitude of 200 m AGL will give a photo resolution of approximately 7 cm. The aerial photographs from both surveys were processed to Orthophoto mosaics and Digital Terrain Models using Agisoft Photoscan software. When using precision ground control points, we are able to achieve a horizontal accuracy for the orthophotomosaic better than 7 cm, and a vertical accuracy of the DTM between 5 and 7 cm. Worldview2 scenes were acquired in three consecutive years 2010, 2011 and 2012.

Field survey, sampling and analysis –The results of the 2011 field campaign demonstrated that the most prominent variations in soil spectra are mostly related to underlying lithology. During the first campaign, which took place in May, more than 280 soil samples were collected for spectral and chemical analysis along 35 sections covering representative parts of the study area. Samples were measured analysed for a number of trace elements: Cu, Pb, Zn, Ni, Cr, Cd. They were analysed similarly to the soil samples. In May 2012 soil samples were collected on predefined traverses in grasslands for spectral and chemical analysis. During the July-2012 soil sampling campaign we exclusively took samples from exposed soil, in contrast to the May-campaign. A total of 144 leaves samples were collected in two different. Leaves samples were collected for laboratory analysis pursuing the following parameters: chlorophyll content, fluorescence and heavy metal content. Leaves from the bottom, middle and top of the canopy plus leaves from one branch, were sampled and stored in a cooler box for a good preserving before reaching the laboratory.

Results and conclusions

The Rosia Montana area is currently in a steady environmental state. There is no active pollution. Chemical and mineralogical background values show trends that are related to mineralisation and hydrothermal alteration, but do not indicate wide-spread pollution as a result of past mining. Spectral analysis of Birch-tree leaves indicates vegetation stress related to mineralisation. Our study indicates that the grass-land ecosystems are potentially most vulnerable to environmental impact, and therefore we focused on detecting degradation of grasslands using field spectroscopy and remote sensing imagery. Given the small scale complexity of the grassland ecosystems, spectral and spatial resolution of the remote sensing imagery are key parameters. Ultra High-resolution UAS-imagery significantly improves our ability to interpret airborne hyperspectral imagery and very high resolution satellite imagery such as WV2. Spectral analysis of WV2, hyperspectral and UAV imagery alllows us to map variations in soil quality at different levels of detail and accuracy. The information collected during the ImpactMin study provides an excellent baseline for future environmental monitoring. Harmonized data calibration and analysis methods were developed to enable standardised time-series analysis for long-term monitoring of key-environmental parameters

Chelyabinsk – Orenburg, Russia

Rosia Montana workflow (tools and methods used):

Data aquistion and analysis - WorldView2, Landsat, ASTER and SPOT-Vegetation images for the Karabash and Mednogorsk demo sites were obtained. The SPOT-Vegetation dataset consisted of a time series of 10-daily NDVI and fAPAR images (S10) from January 1999 to December 2011 at 1/112° resolution (http://www.vgt.vito.be/ and http://www.marsop.info/, n=468). The spectral analysis of images included the derivation of vegetation indices and vegetation related parameters (e.g. NDVI, SDVI, fAPAR), but also using band ratio for soil characterization (iron oxides) etc.

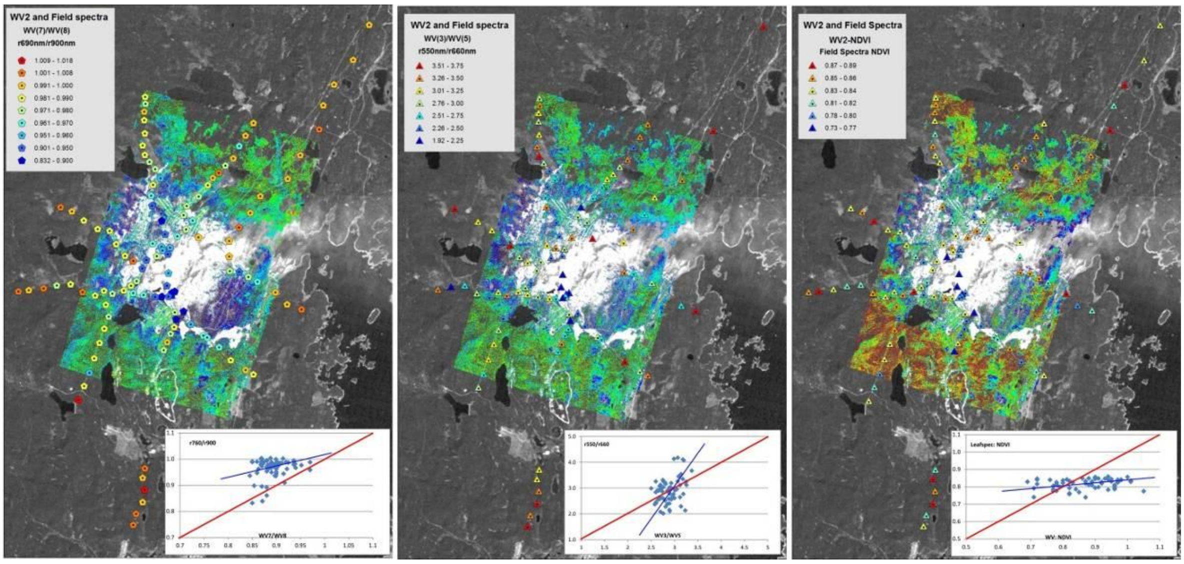


Figure 1- Comparison of vegetation indices derived from WV-2 and from field spectra. The symbols for the samples have the same colour scaling as the images. Red lines indicate a slope of 1. Blue lines indicate the slope for the trends.

Field survey, sampling and analysis – Since there were huge amounts of very different data sampled on thefield, for practical reasons a table is included here to overview them:

Karabash - Media	**Data collection**	**Collection period**	**Type of analyses**
General vegetation	IMIN, UNEXE, GEOS	July and September 2011, July 2012	Visual assessment Infrared Spectroscopy
Lichens, tree and twig bark	UNEXE, IMIN, GEOS	June to September 2011	Lichens and twigs analysed by ICP-MS (UNEXE), pine bark and needles by AAC (IMIN), birch bark and birch leaves by ICP OES (IMIN). pH measured for twigs and bark (IMIN).
Smelter stack dusts	IMIN	July 2010	AAC, ICP-MS

Air filters, snow dusts, snow melt waters	UNEXE, IMIN	February – July 2011	Air filters analysed by ICP-MS and SEM-EDX (UNEXE), snow dusts and waters by ICP-MS & ICP-OES (IMIN)
Soils	IMIN	July 2011, 2012 only Karabash	ICP-OES of soils (IMIN).
Soils	GEOS	July 2011 and 2012	Infra-red Spectroscopy
Surface waters and sediments	IMIN	Waters - end April and July 2011, 2012	ICP-MS, AAC

Results and conclusions

Chemical analyses on soils and vegetation have clearly demonstrated that the main zone of impact extends up to 15 km from the smelter. Spectral analysis of Birch Foliage has demonstrated vegetation stress up to 10 km distance from the smelter. On the basis of these analyses, a number of vegetation indices have been identified that can successfully be applied to map vegetation stress in satellite imagery. Satellite data like Spot-vegetation and Landsat, and in particular WorldView2, are very suitable to map and monitor various important aspects of the environmental impacts related to smelter emissions. There is an excellent correlation in the zonal pattern of impact around the smelter between the data from the IR spectral analysis of birch leaves, the results from time series analysis of multi-temporal satellite imagery and the geochemical data for lichens and soils. Time series analysis of satellite imagery from 1987 to 2011 demonstrates that the environmental situation has not significantly improved despite the installation of the new Ausmelt system. This is confirmed by the comparative chemical study of lichen transplants from 2001 and 2011. The case studies at Karabash and Mednogorsk have shown that the implementation of existing, adapted and new methodologies, whereby in-situ and remote sensing data are combined, may provide a highly sensitive suite of tools for impact monitoring of mining-related activities at different spatial and temporal scales.

The potential impact and the main dissemination activities and exploitation of results

Impacts among the scientific community:

Looking at the recent economic developments and the evolution of the commodity markets, it is becoming more and more evident that in the foreseeable future primary materials will remain as the cornerstone of the full spectrum of the European industry. It is therefore essential that future mining operations as well as the management of current and past operations deploy state-of-the-art and cost efficient methods to monitor and mitigate the impacts of mining activities. The cutting-edge remote sensing technologies that were developed during the ImpactMin project represent cost-effective, reliable and repeatable methods; furthermore, they were based on a thorough end-user requirement assessment and they are adjusted to existing standards and guidelines. As the research agenda of ImpactMin was multidisciplinary, the dissemination efforts targeted several specific audiences based on the scientific content of the Project:

- Impacts of the socio-**economic development on a regional and local level** - lowest carbon footprint options, mining and society
- **Advancement of science and technology** in the domain of satellite and airborne based monitoring techniques
- **Creating standards and uniform methods**
- **Better environmental performance -** understanding of the environmental legacy.

The partners in the Consortium had experience in undertaking leading-edge research and consulting activities, thus they ensured that during (and beyond) the project implementation the valuable outcomes reach the maximum impact at European (and also national) level. The efficient dissemination was manifold and ranging from conventional media use (e.g. articles in mining magazines) to a complex **e-training campaign that facilitated the rapid uptake of the project results**. By employing diverse dissemination methods, the project partners have been able to reach beyond the programme participants (Consortium members, Commission services).

The **scientific content of the Project could reach hundreds of university students** in the field of civil, environmental and mining engineering, primary with the help of the participating universities. There were two occasions at University of Mostar where the project and its achievements were presented to a full-house auditorium in addition to the invited scientific and industrial community. Workshop participants were:

- public authorities (Grad Mostar - PIU Projekt Vihovići)
- third party environmental management organizations (Zagrebinspekt d. o. o., Ecoplan d. o. o. – Mostar)
- local industrial representatives (Aluminij Mostar, EPHZHB) and
- university participants (GFMO) – students and lecturers.

Furthermore, at the Faculty of Civil Engineering, the Project results have been included in the **curriculum of the students**, and examples of methods and their results have been presented in the classrooms. Previously, students from the Faculty helped researchers in the field work and in the analysis of the collected data.

In Sweden, at the Lulea University of Technology, there was a **licentiate thesis** that was based on the Project's Kristineberg demonstration sites activities (Eva Husson: The potential of an Unmanned Aircraft System for surveying lake and river vegetation, 2012 – Department of Civil, Environmental and Natural Resources Engineering Division of Geosciences and Environmental Engineering). The **ImpactMin International Symposium** at the end of the ImpactMin project was attended by several post-graduate and post-doctoral students and by University lecturers to hear the actual research results.

The University of Babes Bolyai hosted the second interim meeting at the beginning of the second year of the Project and besides the **"open day"** at the second day of the meeting, university students (graduate and post graduate) attended the technical presentations and listened to the state-of-the-art scientific outcomes of the different work packages. During the Rosia Montana demo site investigation several students helped and actually contributed to carrying out the scientific research work. It is expected that in 2013 **at least one PhD thesis** will be based on the Rosia Montana site investigations.

At University of Exeter, several **master theses** are based on the carbon footprint investigations of the Project (Jamie R. Keech: Carbon footprint and the Mining industry, 2010 – Camborne School of Mines). Besides, the students the University has employed technical stuff directly dedicated to the Project task purposes.

ImpactMin project presented showcase results on how different mining approaches represent challenges from an environmental and socio-economic point of view at the **Final Symposium in Sweden**. The 48 registered participants at the ImpactMin's final event heard about the research pathways from science and technology, responsible mining – in particular socio-economic survey results and implications and the legislative aspects were highlighted from a pan-European perspective (mining waste directive and inventory) to national perspective. New and cutting-edge geochemical, geophysical and remote sensing tools and methods, which were validated at the Project's demonstration sites, were presented on the second day of the Symposium. The Exhibition and Poster session of the Symposium was a great opportunity to share and discuss technological and methodological innovation from the earth observation and geospatial modelling fields related to the mining/extraction sector (Rikola Ltd. - Finnland, LKAB - Sweden, DMT - Germany, Smartplanes - Sweden etc.).

The accumulated foreground knowledge during the implementation of ImpactMin has been appropriately **disseminated to the wider scientific community** on relevant forums. Internationally recognized lecturers from the staff members of VITO, UNEXE, Geosense and Geonardo attended several professional events with specific focus of the mining research or the earth observation community. The below list shows a selection of such events:

2011 - **Sustainable Development in the Minerals Industry** conference in Aachen, German (UNEXE)
2012 - EARSeL: First International Workshop on "**Temporal Analysis of Satellite Images**", Mykonos, Greece (VITO)
2012 - **Geospatial World Forum** 2012 - Amsterdam, the Netherlands (Geonardo)
Geological Remote Sensing Group, Remote Sensing Workshop - Paris, France (Geosense).

The Consortium members have participated at different thematic events ranging from sustainable and responsible mining forums and they have also addressed the specific geological remote sensing community presenting at specific events like the Geological Remote Sensing Group, the European Associations of Geoscientists and Engineers etc. (full list is included below in the detailed description of work package activities).

The knowledge base of the ImpactMin project has been digested and transformed into an electronic learning material that has been presented primarily via the internet. EO professionals and representatives of the extractive industries can now in a cost- and time-effective way find and learn the necessary information and improve their skills and understanding towards each other. The e-learning training program offers a unique distance learning opportunity to professionals from the Earth Observation (remote sensing) and the extractive industry community.

The web based techniques like e-learning and webinars are becoming very popular in today's internet culture and hundreds and thousands of people search for and learn from electronic scientific material that results from state-of-the-art research activities such as ImpactMin. The free-of-charge project period of **ImpactMin e-Training** was very successful, because the expected hundreds of registrations from all over the world actually have happened and much positive feedback was received by the Consortium and great interest was also expressed for the off-line distribution of the training material. Miners and mining industry professionals from developing countries (e.g. Africa and Asia) were pleased to have the opportunity to learn about the novel techniques and findings of the ImpactMin project. The Project contributed to the targets to help the professionals of the extractive sectors via the e-learning in less advanced regions of the EU and the World and reached stakeholders in Eastern Europe as well to join the process of lifelong learning.

The **Project's LinkedIn activity** also generated noteworthy interest from many countries including USA and the UK and the posts and comments about the Project activities and results were actively followed by industry professionals (Environmental Analyst Group, Mine Planning etc.). Furthermore, collaboration was developed with several scientific groups that was not initially planned; however, news and the **blog posts** about the Project activities and results have taken place at the website of the European Association for Remote Sensing Companies and on the blog of Geology for Global Development's (hosted by the European Geosciences Union).

There were other types of dissemination activities such as **Café Scientifique** (Redruth, Cornwall, UK Title: We are all miners! Responsible mining and ethical sourcing). Also, an **on-line media discussion**[1] took place during the Project implementation where ImpactMin consortia member were represented and thus could brief the greater public about the project's advancements and findings. The event was organized by the Guardian about responsible mining.

Popular Scientific Publications were tailored for the wider stakeholders in the extractive industry, and ImpactMin appeared in a magazine directed for industry professionals and again the research community worldwide. All in all, ImpactMin's **media appearances** were exhaustive and significant.

<u>Exploitation of results (civil society, policy making, employment):</u>

The exploitation of the ImpactMin project's research results are/have been possible on many ways. The major pathways of using the accumulated scientific knowledge is to shape the research agenda on a European scale (European Technology Platform on Sustainable Mineral Resources) and also giving the global aspects with the contribution to the work plan of the Group on Earth Observations (GEO). Additionally, local decision makers and political representatives were reached with the Project's findings. The participating SMEs have used the "momentum" of the ImpactMin project to commercially exploit research results given by the rules of the Consortium Agreement's relevant sections.

ImpactMin consortium has built up a good relationship with policy makers and civil society in Bosnia and Herzegovina. The **City of Mostar was engaged by a Barter Agreement** and the two parties developed a good

[1] http://www.guardian.co.uk/sustainable-business/blog/responsible-mining-live-discussion

cooperation throughout the project's lifetime. Furthermore, civil society end-users and dissemination activities have included:

- Follow-ups with the City of Mostar, Federation of Bosnia and Herzegovina government ministries (February-March 2012), feedback and inputs.
- Briefings and participation at the meetings/conferences with the Helsinki Committee of Bosnia and Herzegovina on the topic of Environment and Human Rights (March 2012 and September 2012)
- Briefing dissemination to the Federal Ministry for Energy, Industry and Mining, Bosnia and Herzegovina (October 2012), feedback and inputs.

Additionally, during the socio-economic study the consortium members informed and interviewed (on all demonstration sites) the relevant stakeholders when performing the socio-economic survey. During these **interviews and briefings, local NGO's and authorities** were contacted and the Mayor of the relevant cities were informed about ImpactMin's objectives and planned activities. Detailed information on these activities can be found in the freely downloadable report at the Project's homepage (Deliverable 3.1).

Since the Consortium partners (e.g. Lulea University of Technology, University of Exeter) are participating in pan-European panels such as the ETP SMR, and will likely be dominant players in the European Innovation Partnership on Raw Materials, it is expected that the political and research agenda will reflect the achievements of ImpactMin projects in the field of sustainable mineral resources exploitation. If these international, multi-sectoral groups will operate effectively and fulfil their mandates, they can actually orientate European decision making in the field of raw materials.

ImpactMin project was in close cooperation with the Group on Earth Observations (GEO) and contributed with several activities to the implementation of the work plans of GEO. **This intergovernmental group is coordinating the international earth observation activities** with providing objectives for the benefits of the greater society. The respective deliverables that detail with the collaboration and achievements can be downloaded at the ImpactMin website.

On a global scale, there is an enormous potential for the application of the developed methodologies. With the necessary improved scientific knowledge base, the participating European consulting and engineering companies could apply the results in other countries and further improving the **competitiveness of European engineering and consultancy SMEs**. The participating universities and research institutes (University of Exeter, VITO etc.) could further develop their prestigious scientific portfolio, thus their involvement in international research networks and additional projects is going to happen. The enormous scientific and technical work that was performed by the Project partners already **yielded in the creation of employment possibilities** in the partnership, thus an increasing rate of employment was achieved. The participating SMEs (Geosense B.V., Geonardo Ltd.) create a potentially new business perspective in the EO consulting businesses, too.

Additional dissemination actions and results listed according to the Description of Work:

End-user surveys and end-user forums

A workshop was organised in Germany with representatives from the mining sector. Two other workshops were also organised, led by IMIN in Russia and Photon in Croatia. A Germany-wide poll was also conducted, based on DMT's network and beyond.

On 26th August 2010 DMT organised a workshop in Essen, Germany. High-ranking representatives from mining companies, public bodies, mining associations and energy companies were invited to the workshop. The aim of the workshop was to get the various participant groups to share their opinions, bearing in mind the objectives, in order to get a better idea of their needs and user expectations. To improve the quality of the debate, several of the participants made presentations (as can be seen in the tables) in order to familiarize the participants on the subject.

Workshop in Germany

This workshop was primarily intended share information between the various parties. The main scope of the workshop included (in the absence of mining companies):

- What kind of EO data can be used by the end users and which technical restrictions might be associated with this? It was difficult or impossible to overcome certain inhibitions, caused by the different/opposing parties having conflicting goals, because of their fear of possible drawbacks
- The other topic was on this event is that there were two driving forces identified or defined when identifying of needs:
    - Demand Driven approach
      That deals with what type of information is needed by the users concerning remote sensing. Different (EO) information is needed for example in the case of "open cast brown coal mining" or when mining operation causing changes in the landscape or when water quality is subject of the monitoring.
    - Technology Driven approach
      There is an extremely broad spectrum here. The quality of the data can also vary widely (e.g. resolutions, size of the area scanned, etc.). However the participant of the workshop were unable to come to any clear agreement about what can't be measured technically, and what is technically possible.

Workshop in Croatia

This workshop was about the joint strategy and emphasis was put on the applicability and potential usability of airborne EO instrument on particular demonstration sites (e.g. Mostar). On the second day of the workshop the Mayor of Mostar participated and the barter agreement was signed by the ImpactMin consortium and the City of Mostar as an end-user/stakeholder regarding the Mostar demonstration site (Bosnia and Herzegovina).

Workshop in Russia

In Russia, the same challenge as in the German Workshop came about - the participants did consider the Project's approach quite broad. The participants would have expected more concrete and applicable information. However, they wanted to be further informed about ImpactMin's progress as the audience were keen to hear more about the tools of Earth Observation that have to be applied in their operations.

End-user relations & Barter agreements

Geonardo, as a legal entity, have so far signed two agreements representing the ImpactMin Project: one with the City of Mostar (Bosnia-Herzegovina) and a second one with the Rosia Montana Gold Corporation based in Bucharest. The above-mentioned barter agreements achieved their purpose as the project benefitted from raw data, field support for later operations for WP6 and WP7. End users will be informed about the results of the project and see how they can potentially continue cooperating with the programme beneficiaries after the project ImpactMin's end.

ImpactMin – Mostar workshop and signature of the barter agreement, Mostar 2010 September 29/2012 November 9

Mining-sector Advisory Committee

Mining Sector Advisory Committee has been set up in the very beginning of the Project and collaboration with the Committee members proved to be successful aiding to keep ImpactMin's focus on track throughout the first period. The cooperation with the Advisory Committee is well planned to continue until the Project's end. Geonardo asked Prof. Janos Földessy (University of Miskolc, Hungary) and Henryk Karas of KGMH Coprun (Poland) to be the members of the Committee. The AC was informed continuously about the proceedings of the Project thus the members of the Committee could give their opinion when it was necessary.

End-user interest monitoring

DMT's task was to establish the “END USER NEEDS AND REQUIREMENTS" based on the objectives defined in work package (WP) 2 and refined in WP 8.
In addition to fairly minor surveys conducted in Germany, the major online survey outlined below was conducted at an international level. The necessary contacts for this survey were recruited from DMT's extended network. The survey was conducted at universities, companies from the raw materials, minerals and mining sectors, environmental authorities, manufacturing industry and technical service providers (construction engineering). In general, the users want data sensing to produce more precise data material and feature a higher degree of user-friendliness. The following points are noteworthy:

- More detailed data quality
- Greater accuracy
- Finer resolution
- Faster results presentations, faster processing and a faster data rate.

Aspects such as automation, simple data processing and more satellite data were also mentioned in this context.

Partner Dissemination Activities

Partners were very active in promoting ImpactMin on several different forums related to mining and extraction, earth observation and in general media. A brief summary can be read below with the input of individual Project members.

Geonardo

- GRSG meeting at ESA premises– poster and oral presentations (Frascati), December 2011
- April 2012: Oral presentation on ImpactMin activities at the Geospatial World forum, April 24-26 2012, Amsterdam; *Abstract; Assessment of environmental impact of mineral resources exploitation using high and very high resolution optical satellite imagery.* M.Goossens and P.Gyuris
- Geonardo Ltd. meeting the delegation of the Ministry of Energy and Natural Resources (MIGEM) of the Turkish Republic (General Directorate of Mining Affairs), 11 October 2012, Budapest.
- Association of Hungarian Geophysicists - Conference and Exhibition on Earth Sciences and Environmental Protection, Miskolc, Hungary, 27-29 September 2012

ImpactMin workshop, Rosia Montana, February 18, 2013 - On the left: Peter Gyuris giving the presentation of ImpactMin project and its overall results, On the right: a photo with the representatives of RMGC

GEOS

- Dec.2011: Represented IMPACTMIN with booth at the General meeting of the Geologic Remote Sensing Group, Frascati
- Dec 2011: Oral presentation on Impactmin activities in Karabash and Rosia Montana at the Annual General meeting of the Geologic Remote Sensing Group, Frascati, Dec7-9, 2011. *Abstract: IMPACTMIN: Monitoring mining-related Environmental Impact,* M.Goossens. P.Gyuris & the Impactmin-team
- March 2012: Represented IMPACTMIN with booth at the conference of the Prospectors and Developers Association Canada, Toronto
- April 2012: Represented IMPACTMIN with booth at the conference of the Geospatial Worldforum, Amsterdam
- April 2012: Co-author of the Poster presentation at EGU 2012, 22-27 April 2012, Vienna, http://www.egu2012.eu/

Extended abstract *Spatial unmixing for environmental impact monitoring of mining using UAS and WV-2*, S. Delalieux, S. Livens, M. Goossens, I. Reusen, and C. Tote

- Sept.2012: Oral presentation on ImpactMin activities in Karabash and Rosia Montana at the European Association of Geoscientists and Engineers (EAGE) Remote Sensing Workshop, Paris, 3-5 September 2012. *Abstract: Environmental Monitoring of Mining Areas; Field Spectra, UAV and Satellite imagery.* M.Goossens, C.Toté, C. Baciu, B. Williamson, V.Udachin and P.Gyuris
- Sept.2012: Represented IMPACTMIN with booth at EAGE, Paris
- Dec. 2012: Oral presentation on ImpactMin activities in Karabas and Mednogorsk at the Annual General Meeting of the Geological Remote Sensing group, Dec 13-16, London. *Abstract: Environmental Impact monitoring using vegetation and soils in the Karabash Smelter area and Mednogorsk.* M.Goossens, B.Williamson, P. Aminov and C.Toté,
- Dec. 2012: Oral presentation on ImpactMin activities in Rosia Montana at the Annual General Meeting of the Geological Remote Sensing group, Dec 13-16, London. *Abstract: Integrated analysis of WV2, Hyperspectral and UAV imagery for environmental monitoring in Rosia Montana, Romania.* M.Goossens, C. Baciu, S. Delalieux, D. Raymaekers, P.Gyuris

UNEXE

- Adey, E., Shail, RK., Wall, F., Varul, M., Whitbread-Abrutat, P., Baciu, C., Ejdemo, T., Lovric, I & Udachin, V. 2011. Corporate social responsibility within the mining industry: case studies from across Europe and Russia. Proceedings of the 2011 Sustainable Development in the Minerals Industry conference, Aachen, 14-17 June 2011, pp 153-170. VGE Verlag GmbH, Essen.
- October 2011: Represented ImpactMin at SR Mining 2011 First International Seminar on Social Responsibility in Mining, Santiago, Chile.
- July 2011: Represented ImpactMin at Environment and Identity Conference, Cornwall, UK.
  Title: Vegetation stress due to mining impact in Karabash using TSA of SPOT-VGT, by Carolien Tote, Marc Goossens, Ben Williamson, William Purvis, David Bellis, Valery Udachin, Else Swinnen and Ils Reusen
- Main author of paper published by Mines and Quarries "Is the Karabash smelter cleaning up its act? Evidence from lichen and satellite monitoring" by Ben Williamson, Frances Wall, Carolien Tote, Marc Goossens, William Purvis, David Bellis, Valery Udachin, Pavel Aminov, Else Swinnen, Ils Reusen and Peter Gyuris

LTU

- Licentiate thesis. Eva Husson 2012. The potential of an unmanned aircraft system for surveying lake and river vegetation. Luleå University of Technology.
- Scientific manuscript submitted to Applied Vegetation Science (major revision). Eva Husson, Olle Hagner & Frauke Ecke. Macrophyte monitoring at the species level using an unmanned aerial system.
- Scientific manuscript to be submitted to Water, Air and Soil Pollution. Eva Husson, Fredrik Lindgren & Frauke Ecke. Assessing Biomass and Metal Contents in Riparian Vegetation along a Pollution Gradient using an Unmanned Aircraft System.
- Poster presentation at the 13th International Symposium on aquatic plants, 27-31 August, Poznan, Poland. Eva Husson, Olle Hagner, Fredrik Lindgren & Frauke Ecke 2012. Macrophyte monitoring at the species level using an unmanned aerial system.
- Oral presentation at the 13th International Symposium on aquatic plants, 27-31 August, Poznan, Poland. Sebastian Birk & Frauke Ecke 2012. Opportunities and limitations of remote sensing in ecological status monitoring – a case study of Swedish humic lakes.
- Oral presentation (invited speaker) at the Geo-Info conference 2-3 October, Uppsala, Sweden. Frauke Ecke 2012. Obemannade flygplan inom miljöövervakningen – bara fantasin sätter gränser.
- Oral Presentation (invited speaker) at Workshop on Future Techniques in Environmental Monitoring, Swedish University of Agricultural Sciences, Uppsala, Sweden. Frauke Ecke 2012. Recent advances in remote sensing techniques for future environmental monitoring.

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- Geological Workshop: Geological Union of Bosnia and Herzegovina: Environmental and emergency remote sensing. Lecturer: Amer Smailbegovic, Photon llc. October 11, 2011
- Presentations at ImpactMin progress meeting, 15-16 February 2012, Cluj (Romania)
- Geological Society of Nevada, USA: Measuring impact of mineral activities on the environment using EO. Lecturer: Amer Smailbegovic, Photon, September 25, 2012
- University of Mostar, Bosnia and Herzegovina: ImpactMin measurements and site report. Lecturers: Roko Andricevic, Mak Kisevic, Amer Smailbegovic (Photon llc), Mirna Raic (GFMO) - November 9, 2012
- Aluminij Mostar d.d. (corp.) – Presentation of the data acquired at the Red-mud storage area at Dobro Sel – briefing to the environmental protection directorate of the company.
- University of Zenica, Bosnia and Herzegovina: ImpactMin Project - measurement of environmental impacts, future directions. Lecturer: Amer Smailbegovic. December 21, 2012

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- Aug. 2011: Oral presentation on Impactmin approach and activities in Rosia Montana at the Goldschmidt Conference, Aug. 14-19, 2011, Prague. Absract: *Enhancing the accuracy of the environmental monitoring systems in mining areas,* C. Baciu, D. Costin, C. Pop, L. Lazar. Published in *Mineralogical Magazine*, 75, p. 466.
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- Poster presentation at EGU 2012, 22-27 April 2012, Vienna, http://www.egu2012.eu/
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ImpactMin Final Symposium – Luleå 27-28 November 2012