# Application of remote sensing imagery for environmental changes

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**ZUSAMMENFASSUNG :**

*Die Fernerkundung kann eingesetzt werden zu den Beobachtungen verschiedener Umweltdaten. In dem Vortrag wurden zwei Beispiele aus Polen gegeben: ein Braunkohletagebau in Belchatow und ein Schwefelbergwerk in Jeziorko. Für diese zwei Beispiele wurden die Ergebnisse einer klassischen Bildverarbeitung präsentiert. Die Kartenbearbeitung wurde aufgrund einigen multispektralen und multitemporalen Aufnahmen von Landsat TM, SPOT sowie einigen Flugzeugfarbaufnahmen gemacht. Es wurden beispielhaft eine Bildverarbeitung für multi-hyperspektrale Flugaufnahme und für Satelitaufnahme für die zwei Bergbaugebiete präsentiert. Eine Klassifizierung für Jeziorko wurde ebenso gemacht. Die Daten für Fernerkundung wurden aufgrund der spektrometrischen Messungen vor Ort bearbeitet.*

**ABSTRACT:**

*Remote sensing technology could be implemented in environmental monitoring. Two examples from Poland have been analyzed: Bełchatów open-pit mine and sulphur mine region in Jeziorko. Results of "classical" remote sensing images processing is presented. Multispectral and multitemporal Landsat TM, SPOT and color airborne images was used for mapping mining area in Belchtów open pit-mine. An example of multi-hyperspectral airborne and satellite imaging for abandoned mine site classification in sulphur mine region in Jeziorko is also presented. Remote sensing images was processed using results of in situ spectrometer terrestrial measurements.*

## 1 Introduction

Remote sensing technology could be apply to object and phenomena recognition. Environmental changes are monitored by comparison the suitably prepared results of analyzing the remote sensing imageries from different time points. Many platforms provide imagery from space. There are the satellite platforms: Landsat, Spot, IRS, Ikonos, QuickBird etc, and also local airborne platforms. Traditional commercial images as well as a new one are available for the applications. Nowadays remote sensing is developing in three directions: improving spatial, spectral and radiometric resolution of scanners. Hyperspectral data are recorded on the base of imaging and non imaging spectrometers. Non imaging spectrometers produced by different companies, the most famous: Analytical Spectral Devices Inc. (ASD) and Geophysical & Environmental Research Corp. (GER) allow the point's measurements. The results of measurements can be presented as a diagram of changes of the reflection/emission coefficient with the wave length. Spectral range is very dense sampled, with the resolution of 0.01 – 0.001 μm. Amount of the measurements is from several hundreds to several thousands.

Second group of spectrometers are imaging spectrometer, for example AVIRIS - Airborne Visible/Infrared Imaging Spectrometer (224 channels). Generally the spectral resolution of imaging spectrometers is worse in compare to non imaging and is from dozen to several hundred channels. There are also spectrometers (for example ASTER) imaging in a dozen channels, more than in “classical” multispectral scanners (3 to 7 channels) but not really hyperspectral.

# 2 Methodology

Remote sensing images applied for environmental changes are processed in classical way:
Preprocessing for geometry and radiometry correction,
Information extraction, focused on the researched problem (change analysis),
Final image preparation for presentation.

## *2.1 Preprocessing for geometry and radiometry correction*

Raw, satellite or airborne remote sensing data have to be initially processed. Usually, images are calibrated to the unique coordinate system, for example for its integration in GIS. The procedure is composed with coordinate transformation basing on the control points, and *resampling* procedure, for generating a new image in a desired coordinate system. Also in this phase images are radiometric corrected for sensor errors removing (ex. *destriping*, Abb. 1), or to remove the noise or to repair the missing lines.

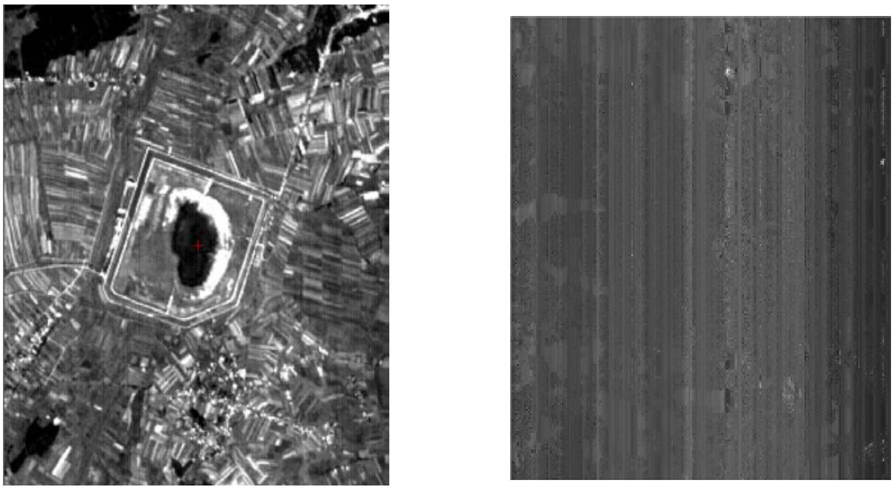


Abb.1 : An example of *destriping* procedure (left – image affected by sensor noise, right – noise image); reservior in Jeziorko.

## *2.2 Information extraction, focused on the researched problem*

The main part of image processing is the information extraction, perform visually by specialist or with the help of automatic or semiautomatic image transformations, like unsupervised or supervised classification techniques (Abb.2), classification basing on the specially for individual purposes developed classification algorithms, or more sophistical models (erosion models, thermal inertia models, biomass assessment models etc.).
At present in remote sensing appears imagery composed of the huge amount of channels from dozen to several hundred. For comparison, traditional, well known multispectral satellite: LANDSAT TM has 7 channels. The mentioned above techniques for image processing were developed specially for multispectral images having a few channels max. 7. But if there is no limits in used software (no limits of processed channels) the algorithms developed for multispectral images could be applied also for hyperspectral images processing.

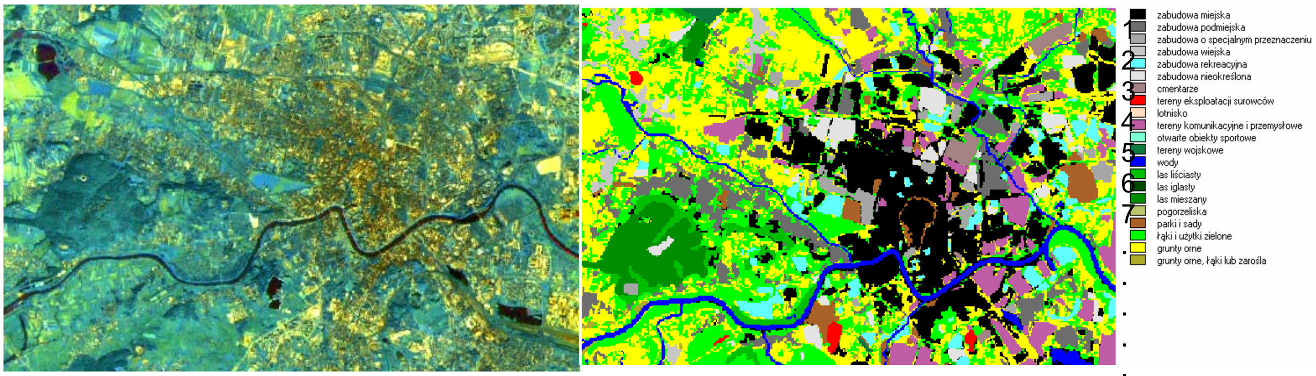
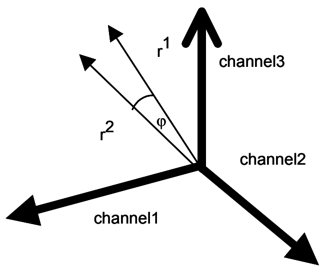



Abb.2 : An example of supervised classification (left – satellite image: Landsat+ IRS PAN, right – result of classification); Cracow center.

Besides the special methods of hyperspectral image processing are developed, for example Spectral Angle Mapping (SAM). In this method spectral measurements of the reference object or reference object class allow to build reference vector. The spectral values in the channels define the coordinates of reference vector. Reference vector could be constructed from spectrometer measurements of the object or basing on the pure class objects test sites defined on the image. On the Abb.3, form spectral curve, n-dimensional reference vector of *n*-coordinates is calculated ($r^1$). Coordinates of the vector ($r^1$) are equal spectral values corresponding to each channel width of the image. Each pixel of analyzed image is also a vector ($r^2$) of *n*-coordinates corresponding to spectral value in channel. Next, the angle between the vectors is calculated and the classification of the pixel is performed after comparison the value of calculated angle with the assumed limit value.




$$\varphi = \cos^{-1}\left(\frac{\boldsymbol{r}^1 \cdot \boldsymbol{r}^2}{|r^1||r^2|}\right)$$

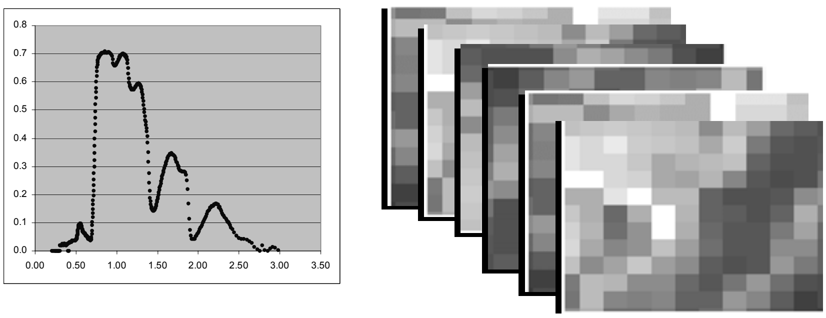


Abb.3 : Spectral Angle Mapping basing on the spectral curve

Changes monitoring could be performed basing on the results of image processing registered in different time. The multitemporal results could be for example subtracted and the difference image is to be analyzed. Another possibility is to analyze all combinations of pixel value from all channels from all times (*cross correlation*). In the image processing packages are different procedures for so called time series analyzes implemented.

At the end the results are finally processed for change analysis presentation.


Abb.4 : Presentation of test area.

# 3 Belchatów open-pit mine test area.

Content of the paragraph is a part of research conducted in the Department of Photogrammetry and Remote Sensing Informatics at the UMM and published among the others [Mularz S. 1998].
"The Belchatów Mining Energy Complex (BMEC) being investigated, is located in the Middle Poland, 6.5 km south the City of Lódz. The BMEC consists of two parts: lignite open-pit mine with the dump body (350 m in high) and electric power plant (Abb.4). There is a mining over 30% of the lignite production in Poland, and electric plant gives of 10% of the country electric energy amount.
The deposit body of 55 m thick, occurs 150-250 m beneath the ground level and spreading out of 3 by 25 km parallel to the latitude (E-W).
The environmental impacts have been started over 25 years ago, since initial works, particularly under-ground water drainage system have been turned on. The next step of the environmental degradation process appeared 10 years after, when the electric power plant has been started with the gasses and dustfall emission."

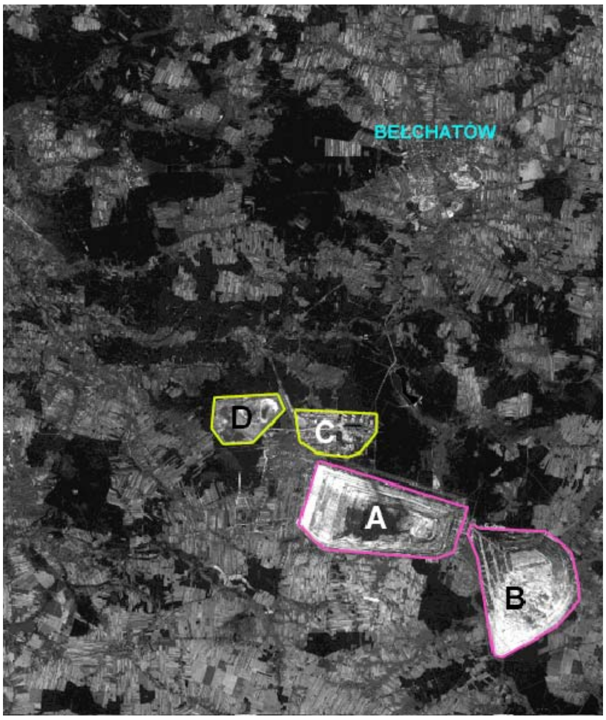



Abb.5 : SPOT PAN image over the study area (A - open-pit-mine; B - dump area; C - electric power plant complex; D – slag&ashes containers)

For the environmental change analysis the following set of data have been used:
1) SPOT-PAN imagery, acquired on 29 August 1990;
2) Set of cartographic data, such as:
topographic maps (scale: 1:200000, 1:50000);
inventory map of vegetation cover on the overburden dump area (scale: 1:8500); the map was compiled on the base of photointerpretation of the black and white aerial photographs, on 4 July 1987;
3) reports of reclamation activity on the dump area contained the results of the ground inventory works

Estimation of reclamation activity on overburden dump area consists of:
1) inventory of vegetation cover with discrimination of four categories (Abb.6 A):
a) deciduous forest;
b) brushwood and grass;
c) brush and tress;
d) grass;
2) quantitative approach to the assessment of the reclamation activity over the dump area.
For this purpose two maps were generated:
a) map of vegetation cover changes on N-W part of the dump area (Abb.6 B);
b) map of the reclamation stages with the five zones ;
- reclamation finished 4.2 %
- reclamation advanced 10.3 %
- reclamation initial 28.9 %
- reclamation experimental 18.9 %
- dumping & geomechanical operations 36.2 %
unclassified 1.5 %

| | |
|---|---|
| Total | 100.0 % |

map of changes between inventory map prepared on the base of visual interpretation of the airborne images (1987) and digital map prepared on the base of SPOT image (1990), (Abb. 6 C).

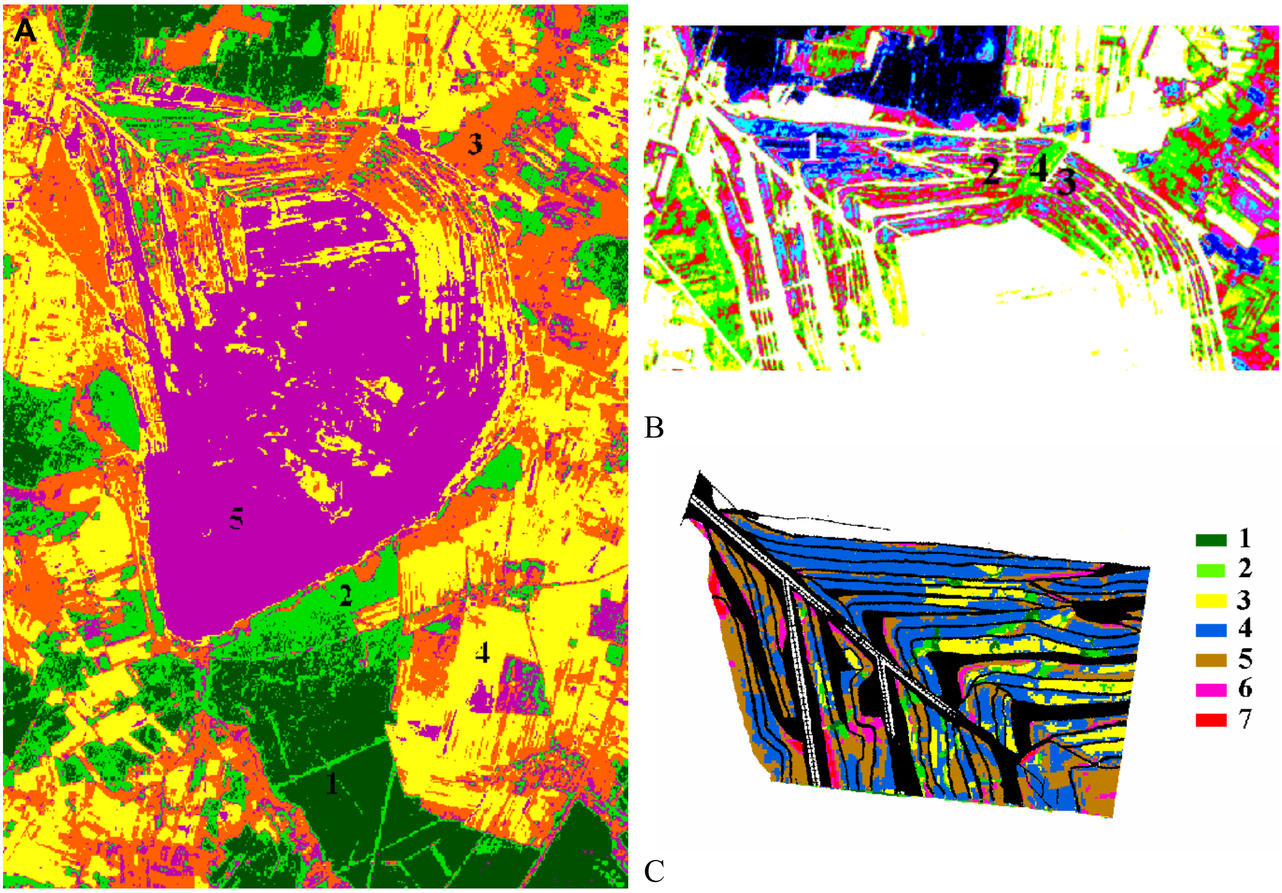



Abb.6 : Changes monitoring on the dump area in Belchatow open-pit mine:

- A - Map of land-cover over the dumping area (1-conifer forest; 2-deciduous forest; 3-grass-land&urban; 4-crop-land; 5-baregrounds);
- B - Map of vegetation cover the N-part of dumping area – supervised classification of SPOT (XS+P) (1-deciduous forest; 2-brushwood&grass; 3-brush &trees; 4-grass);
- C- Map of the vegetation cover changes of the N-W part of the dumping area (category: 1,2,3-changes in plus; 4-no changes; 5,6,7-changes in minus).

## 4 Jeziórko sulphur test area.

In the mining area Machów/Jeziorko 3 mines were placed: Machów – open mine, Jeziorko and Grzybów – drilling technology. In 1980 total production was above 5Mt of sulpuhe, and Jeziorko mine was the biggest one in the world. In 1996 exploitation was stopped cause the sulphur price degrees. Degradated area cover about 1700 ha. The reclamation costs are of 20 000 – 50 000 PLN/ha. The sulphur pollutions caused the soil acidation. Generally during the reclamation works acid soil layer is removed ex. to the open mine Machów and the rest pollution is neutralized with limestone. The second effect of sulphur exploitation is ground water condition changes and surface deformations [Gołda T.1994].

For Jeziorko region there is no actual maps. Mining maps during sulphur production consist of the engineering objects important in that phase of the mining area development. There is no money for register the reclamation stage. In this case any remote sensing data could help in inventory maps preparation. The main aim of the research was to find correlation between the remote sensing imagery and the sulphur ground contamination.

### *4.1 Remote sensing data*

During initial research, image from ASTER was free downloaded by *ftp* from USA governmental server (http://asterweb.jpl.nasa.gov) from 15$^{th}$ of July, 2001. ASTER channel characteristics are shown in Tab.1.

Tab.1 : ASTER channels

| System | Channel number | Spectral range [µm] | Spatial resolution |
|---|---|---|---|
| VNIR | 1 | 0.52-0.60 | 15 m |
| | 2 | 0.63-0.69 | |
| | 3 | 0.76-0.86 | |
| SWIR | 4 | 1.60-1.70 | 30 m |
| | 5 | 2.145-2.185 | |
| | 6 | 2.185-2.225 | |
| | 7 | 2.235-2.285 | |
| | 8 | 2.295-2.365 | |
| | 9 | 2.36-2.43 | |
| TIR | 10 | 8.125-8.475 | 90 m |
| | 11 | 8.475-8.825 | |
| | 12 | 8.925-9.275 | |
| | 13 | 10.25-10.95 | |
| | 14 | 10.95-11.65 | |

In 2002 has been realized project: "Airborne spectrometry for abandoned mine site classification and environmental monitoring at the Machów sulphur mine district in Poland", HS2002-PL4. This is part of 5th Program of UE HPRI-CT-1999-00075: „HySens - DAIS / ROSIS Imaging Spectrometers at DLR" ( http://www.op.dlr.de/dais/hysens/). Project was prepared with the cooperation between UMM Krakow in Polad and TU Clausthal in Germany. Thanks this project was possible to obtain some airborne hyperspectral images from scanners: DAIS 7915 and ROSIS (Tab. 2). Because of the bad weather for Jeziorko test area only some limited hyperspectral data were recorded, and are not processed as yet.

Tab.2 : DAIS 7915 and ROSIS scanner parameters

| | DAIS 7915 | ROSIS |
|---|---|---|
| Scanner type | whisk broom | push broom |
| Number of spectral bands | 79 | 115 |
| Spectral range | 0.5-12.5 mm | 430-860 nm |
| Number of cross track pixels | 512 | 512 |
| Radiometric quantisation | 15 bit | 14 bit |
| Instantaneous field of view | +/- 26$^{o}$ | +/-8 $^{o}$ |
| Total field of view | 3.3 mrad | 0.56 mrad |
| Fligh altitude | 1500-7500 m | |
| Pixel size at 1.5 km fligh altitude | 2.6 x 2.6 m$^2$ | 0.8 x 0.8 m$^2$ |


Abb.7 : ASTER and DAIS (h=1890 m) scanner images.

On the Abb.7 an example of ASTER and DAIS images of part of Jeziorko sulphure mine is shown. During the flight campaign *in situ* measurements are made:
Spectrometer measurements in visual and infrared range (0.45 – 2.5 μm),

Spectrometer measurements in thermal infrared range (2 – 14 μm),
Ground sampling for laboratory estimation of sulphur content.
The project is on going and only partially results are available.

## *4.2 Laboratory spectrometer measurements in TIR range*

### *4.2.1 Instrument description*

Department of Photogrammetry and Remote Sensing Informatics UMM in Cracow has spectrometer μFTIF produced by Design&Prototypes form USA [Hook S.J. Kahle A.B. 1996] (Abb.8). Spectrometer (16 kg) is composed by two parts: optical and electronic. Optical part of 4 kg weight has: intereferometer, detector and optic for measuring and observation of the object. Michelson interferometer allows to obtain spectral resolution of 6 $cm^{-1}$. In optic part are two detectors: InSb and MCT allowing thermal radiation registration in range: 2-5 μm and 5 -14 μm. Focus length is 2,5 cm and from 1 m a surface of 7.6 cm is registered. Optical part is thermoelectrically cooled. In electronic part is laptop, panel converting signal from spectrometer to the computer and the black body reference. Black body reference can be heated and cooled to the suitable temperature. Accuracy of emissivity coefficient estimation according producer is equal in range 8-14 μm: +/- 0.02μm, and in 3-5 μm:+/- 0.04μm.

Optical part has to be cooled before the measurements during 30 min. Measurement contains thermal radiation registration of:
Object,
Black body reference in temperature below the object,
Black body reference in temperature above the object,
Background (ex. sky)
Software for emissivity coefficient calculation is delivered with the spectrometer.


Abb.8 : Spectrometer μFTIF - optical part, (test site in Jeziorlko)

### *4.2.2 Results of laboratory measurements using $\mu$FTIF spectrometer*

As a reference the specially prepared sand/sulphur mixtures were measured using Design&Prototypes thermal infrared spectrometer. Results of the reflection measurements from sulphur with different corn size were downloaded from the JPL library. The reflection coefficients were calculated to emissivity (emissivity coefficient = 1 – reflection coefficient). On the Abb.9 (left side) the transformed results from the library of JPL are shown. The effects of emissivity coefficient measurements by Design&Prototypes thermal spectrometer are presented on the right side of Abb.9 . Please notice a very good correlation with the library curve.

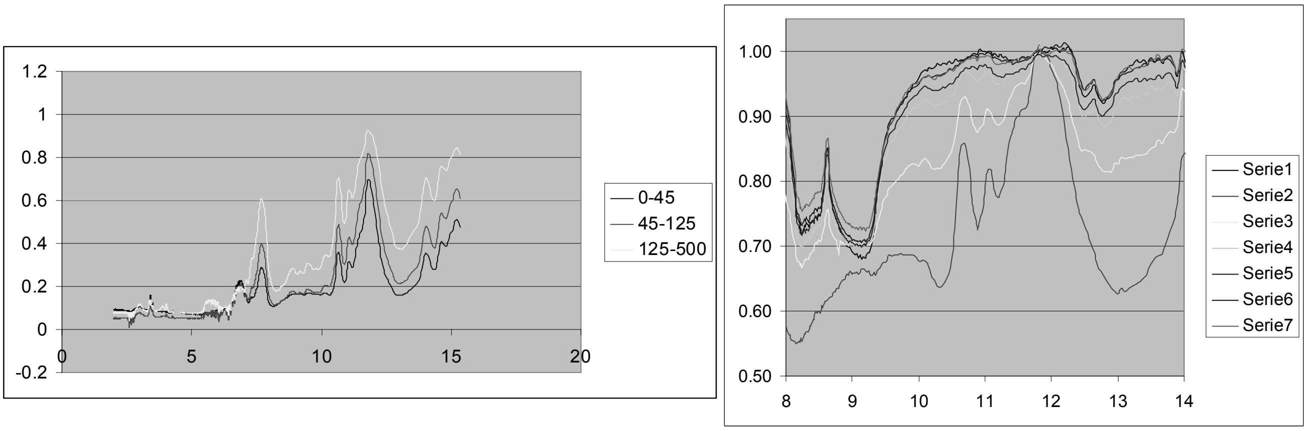



Abb.9 : Left side of diagram – correlation between emissivity coefficient ($\varepsilon$) and wave length ($\lambda$[$\mu$m] for sulphur of different corn size ($\mu$m), [on the base on library data from http://asterweb.jpl.nasa.gov], right side – results of laboratory spectral measurements of sulphur/sand mixture samples:

- serie 1 – 100% of sand,
- serie 2 – 100% of sulphur,
- serie 3 – 50% of sand, 50% of sulphur,
- serie 4 – 80% of sand, 20% of sulphur
- serie 5 – 90% of sand, 10% of sulphur
- serie 6 – 95% of sand, 5 % of sulphur
- serie 7 – 98% of sand, 2% of sulphur.

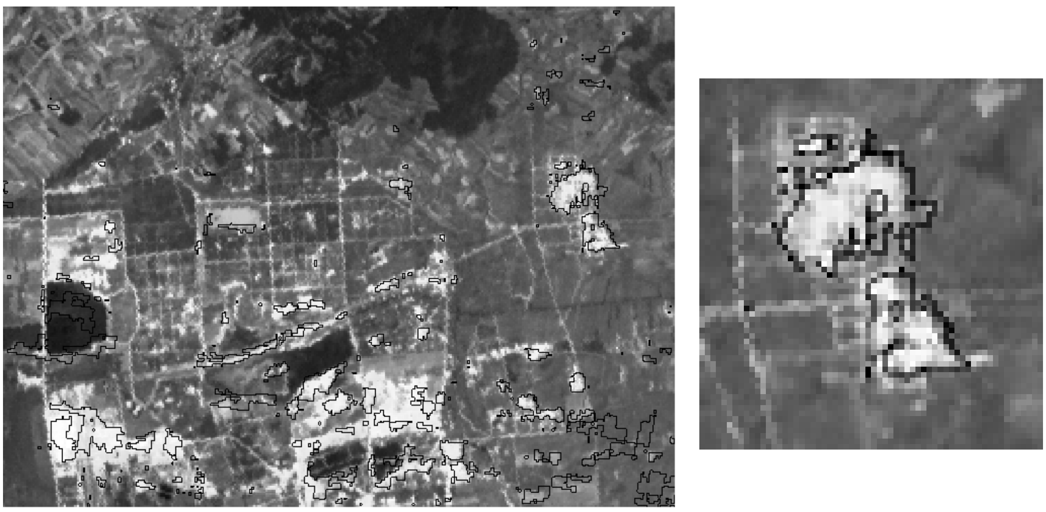


Abb.10 : Result of SAM on the base of spectral curve of Abb.8

## 5 Summary.

In the paper two application of remote sensing in mining area in Poland have been presented. One of it is based on traditional, among others, visual interpretation of remote sensing images. The second application concerned new technology just developing, namely hyperspectral imagery. The last application is on going so only an initial results have been be presented.
Hyperspectral imagery is relatively new and investigations of spectral characteristic of degradated soils would have both research and utilities character. Knowledge of soil spectral characteristic changes caused by its pollution would allow to join the remote sensing methods in soil degradation monitoring before and during reclamation works.

## 6 Literature.

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