Hyperspectral Remote Sensing

A New Tool in Soil Degradation Monitoring

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Hyperspectral Remote Sensing - A New Tool in Soil Degradation Monitoring. *Applications of hyperspectral remote sensing images are still in initial research phase. In the paper an example of application of hyperspectral airborne and satellite imaging for abandoned mine site classification in sulphur mine region in Jeziorko (south of Poland) is presented. Remote sensing images were processed using results of in situ spectrometer measurements. This technology could be applied to monitoring environmental changes by comparing the results of analysis of the remote sensing imageries from different time points. A project: "Airborne spectrometry for abandoned mine site classification and environmental monitoring at the Machów sulphur mine district in Poland", HS2002-PL4 In 2002 was realized. 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/). The project was prepared with the cooperation between AGH University of Science and Technology in Cracow (Poland) and the Technical University in Calusthal (Germany). Thanks to the project airborne hyperspectral images from scanners: DAIS 7915 were recorded. Flight campaign and field measurements of soil radiation were carried out between 1- 4 August 2002. The research concentrated on sulphur mine district in southern Poland, in Jeziorko. Sulphur pollution cause the soil acidation. Degradated area covers about 1700 ha. There are no up-to-date maps of the reclamation stage for Jeziorko region. In this case any remote sensing data could help in inventory maps preparation. The main aim of the research was to find a correlation between the remote sensing imagery and the sulphur ground contamination. Remote sensing could be the an innovative and advanced method of locating and monitoring environmental risks related to a mining site and could help in mapping the soil contamination and monitoring the reclamation process. The research activity also provides information about environmental status and the processes around the mine site. The use of remote sensing methods offers an important alternative to a conventional mapping procedure and could contribute to a development of GIS related analysis techniques for a better understanding of pollution migration processes.*

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Environmental changes could be monitored by comparing the results of the analysis of the remote sensing imageries from different time points. Many platforms provide imagery from space. There are following remote sensing platforms: satellite - Landsat, Spot, IRS, Ikonos, QuickBird etc, and also local airborne platforms - AVIRIS (Airborne Visible Infra-Red Imaging Spectrometer), OARS (The Operational Airborne Research Spectrometer). Traditional commercial images as well as a new one are available for the applications. Registration of earth surface is going to be more attractive thanks to the improvement of spatial, spectral and radiometric resolution of scanners. Hyperspectral remote sensing data can be obtained from imaging and no imaging spectrometers. No imaging spectrometers allow point's measurements and are produced by several companies ex. Analytical Spectral Devices Inc. (ASD) and Geophysical & Environmental Research Corp. (GER) the results of measurements can be presented as a diagram of changes of the reflection/emission coefficient with the wavelength. Spectral range is very densely sampled, with the resolution of

0.01 – 0.001 mm. The number of the measurements is from several hundreds to several thousand.

The second group of spectrometers are imaging spectrometers, for example AVIRIS - Airborne Visible/Infrared Imaging Spectrometer (224 channels). In general, the spectral resolution of imaging spectrometers is worse than that of the non imaging ones and is from a dozen to several hundred channels.

There are also spectrometers imaging in dozen channels like ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer). This spectrometer records remote sensing data in 14 channels, so more than in "classical" multispectral scanners (3 to 7 channels). ASTER is also interesting because of:

- high spatial resolution (VIS)-Visible and (NIR) – Near Infra Red resolution is 15m;
- the images can be obtained by *ftp* from USA governmental server (http://asterweb.jpl.nasa.gov) for free.

Images applied to this project come from this server.

1. Jeziórko sulphur test area

There are three mines in the mining area Machów/Jeziorko: Machów – an open mine, Jeziorko and Grzybów – drilling technology. In 1980 the total production was above 5Mt of sulphure, and Jeziorko mine was the biggest one in the world. In 1996 the exploitation was stopped cause the sulphur price degrees. The degradated area covers about 1700 ha. The reclamation costs are between 20 000 – 50 000 PLN/ha. The sulphur pollution caused the soil acidation. Generally, during the reclamation works thr acid soil layer is removed ex. to the open mine Machów and the rest of the pollution is neutralized with limestone. The second effect of sulphur exploitation is ground water condition changes and surface deformations [Go³da T.1994].

There are no up-to-date maps for Jeziorko region. Mining maps drown at the time of sulphur production consist of the engineering objects important in that phase of the mining area development. There is no money to 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 a correlation between the remote sensing imagery and the sulphur ground contamination.

2. Data

The project: "Airborne spectrometry for abandoned mine site classification and environmental monitoring at the Machów sulphur mine district in Poland", HS2002-PL4 was done in 2002. During the project airborne hyperspectral images from DAIS 7915 scanner were recorded. During the campaign the weather was not ideal and therefore only some limited hyperspectral data could be recorded.

Additionally within the project some field and laboratory measurements were performed using 2 field spectrometers:

- Design&Prototypes (2-14 mm) belonging to AGH University of Science and Technology in Cracow;
- ASD (0.4-2 mm) belonging to Technical University in Calusthal.

This field work is the background for the image analysis. The aim of the field research activity was testing the sulphur contamination as a rest of the abandoned surface mining. The results of preliminary analysis leads to the conclusion that the soil contains various amount of sulphur impurities. The field spectrometer measurements are not yet prepared well enough to be presented.

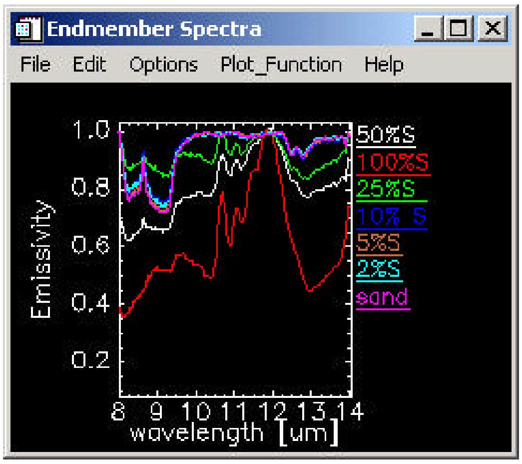
3. Methodology

3.1 Laboratory measurements

Complete range of studies covers processing of spectral images, as well as preparing the results from laboratory measurements. Seven specially prepared samples (sand/sulphur mixtures) were used as a reference. Results of laboratory spectral measurements of reference soils are presented on Fig. 1.

The mixtures were measured using Design&Prototypes thermal infrared spectrometer.

Results of the reflection measurements from sulphur with different corn size were downloaded from the library of Jet Propulsion Laboratory - California Institute of Technology (JPL), [http://asterweb.jpl.nasa.gov]. The reflection coefficients were calculated to emissivity as following: emissivity coefficient = 1 – reflection coefficient. On the Fig. 2 the transformed results from the library of JPL are shown with comparison to the emissivity coefficient measurements by Design&Prototypes thermal spectrometer. A very good correlation between the results from Design&Prototypes thermal spectrometer and the library curves can be noticed.



1 - 0% sulphur 100% sand
2 - 100 % sulphur 0% sand
3 - 50 % sulphur 50% sand
4 - 25% sulphur 75% sand
5 - 10 % sulphur 90% sand
6 - 5 % sulphur 95% sand
7 - 2% sulphur 98% sand

Fig. 1
Results of laboratory spectral measurements of sand/sulphur mixtures

3.2 Processing of multispectral ASTER images

ASTER data set, downloaded from NASA server (http://asterweb.jpl.nasa.gov), contains channels of VNIR (Visible Infra-Red) SWIR (Short-wave Infra-Red) and TIR (Thermal Infra-Red) (see Tab.1). The VNIR and SWIR channels were preprocessed by NASA and delivered to the user in *hdf* files. TIR channels were not preprocessed and that is why this spectrum was excluded from further elaboration. The ASTER data (scene nr 161515 of 2 July 2002) were processed using the ENVI software, a special tool disigned to process airborne and satelite multi or hiperspectral images. ENVI allows to display and analyse images of any size and data type, works with entire image files, individual bands,

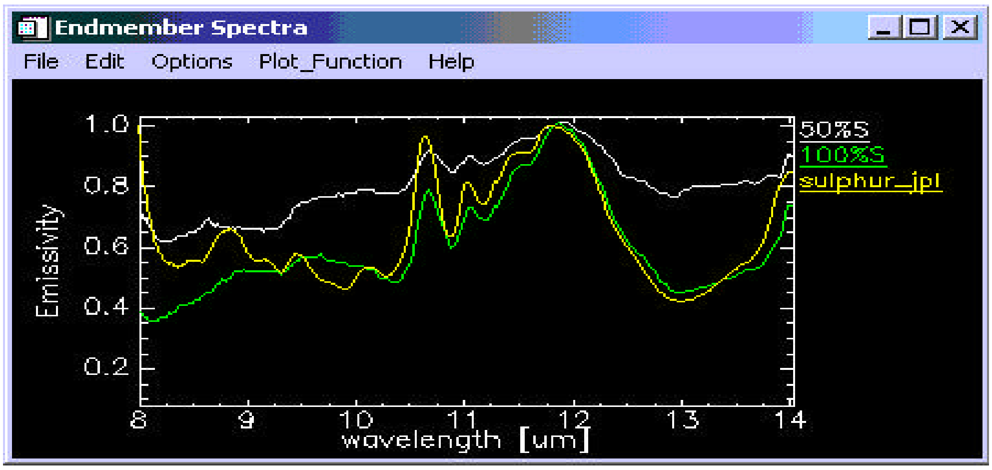


Fig. 2
Comparison with JPL library and laboratory measurments

or all bands recorded in one file. This software enables carring out geometric correction and radiometric processing of remote sensing data. It also includes tools for analysis high spectral resolution images data set, basing on spectral libraries or on extracted from images spectra. Figure 3 illustrates the technology of image processing implemented in ENVI. This approach is for the analysis of hyperspectral data and all further procedures are in general terms its implementation.

VNIR 15 m	SWIR 30 m	TIR 90 m
Band 1 N:	Band 4:	Band 10:
0.52 – 0.60 μm	**1.600 – 1.700 μm**	**8.125 – 8.475 μm**
Band 2 N:	Band 5:	Band 11:
0.63 – 0.69 μm	**2.145 – 2.185 μm**	**8.475 – 8.825 μm**
Band 3 N:	Band 6:	Band 12:
0.76 – 0.86 μm	**2.185 – 2.225 μm**	**8.925 – 9.275 μm**
Band 3:	Band 7:	Band 13:
0.76- 0.86 μm	**2.235- 2.285 μm**	**10.25 – 10.95 μm**
	Band 8:	Band 14:
	2.295 – 2.365 μm	**10.95 – 11.65 μm**

Tab. 1
ASTER channels

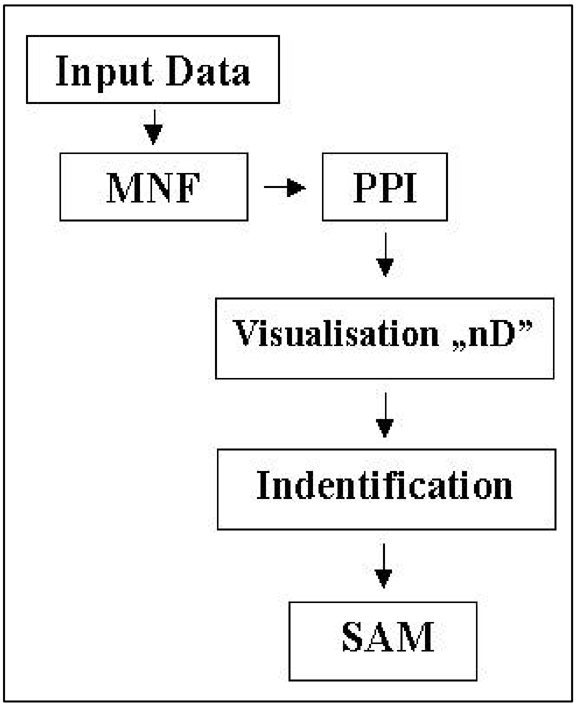


Fig. 3
Steps of ASTER images processing in ENVI software

ASTER images have different spatial resolutions. VNIR and SWIR channels have pixel size, respectively 15 and 30m. To further processing, all images have to be in the same resolution. SWIR images were resampled to the size of VNIR channels (15m of pixel size).

The next step is transformation of Minimum Noise Fraction (MNF). The MNF method is used in ENVI software to analyse the correlation between images and reduce noises, what is very important in analysis of dozens or even hundreds of bands. The MNF function identifies the noises and then allows the bands classification according to their usefulness to futher processing. The channels could be ranged from images included the most useful information to noise-dominated images. MNF method is based on Principal Components (PC) transformation. As a result of the transformation the bands without band-to-band correlations and bands containing only noise, not used in subsequent processing, were obtained. The data dimensionality can be determined from the eigenvalues by finding where the slope of the eigenvalue curve breaks and the values fall off to 1. By examining the plot and comparing the eigenvalues with the image after MNF transformation one can find out the information about the spectral quality of the image (Fig.4)

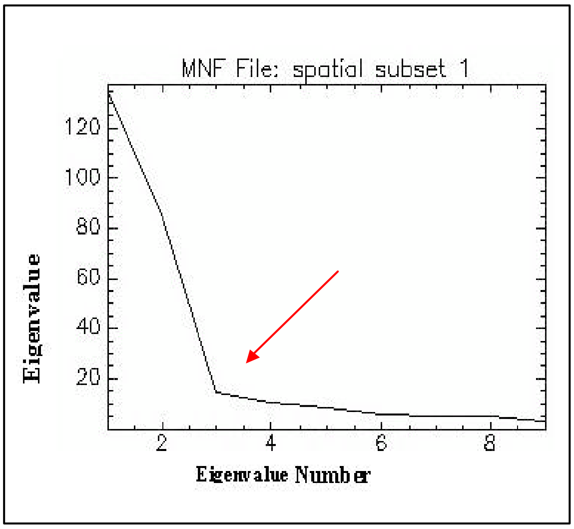


Fig. 4
ENVI MNF eigenvalue plot

The results of MNF transformation are used for Pixel Purity Index (PPI). The main aim of the algorithm is to extract the “spectrally pure” pixels, so called endmembers from a multi or hyperspectral image. Algorithm generates suitably large number of random n-dimensional vectors (n-number of bands). For each vector every data point is projected on to the vector and the position of the point along the vector is noted. Pixels which fall onto the end of the unit vector are the extreme pixels and their number is counted. This quantity defines Pixel Purity Index. Final number of pixels can be selected using a pixel threshold value to refine the selection. The accuracy of Pixel Purity Index algorithm depends on number of iterations which were executed. In this case there were 20 000 iterations.The number of pixels selected in PPI corresponds to ca. 5% of the whole number of pixels in the image (black coulor points in Fig. 5).

The relationship between the reflection/ emissivity coefficient and the wave length can be represented as a spectral curve. The other way to show this relation is by “spectral cloud” - a group of points in n-dimensional space whose coordinates are the spectral response of individual bands.

The “spectral cloud” shows how spectrally different are the pixels depending on the spectral characteristics of the material (see Fig. 6.) .

In the scatter plot (2-dimensional) different kinds of land cover can be recognised. In this way we can initially classify the image. A precise recognition of the pixels can be made in n-Dimensional Visualizer.

Spectrally pure pixels are the input data for SAM Spectral Angle Mapping. In this method spectral measurements of the reference object or reference object class allow to build an n-dimensional the 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 on the basis of the pure class objects test sites defined on the image. For ASTER, “n” is equal 14 and each pixel of the analyzed image is also a vector of n = 14 coordinates corresponding to the spectral value

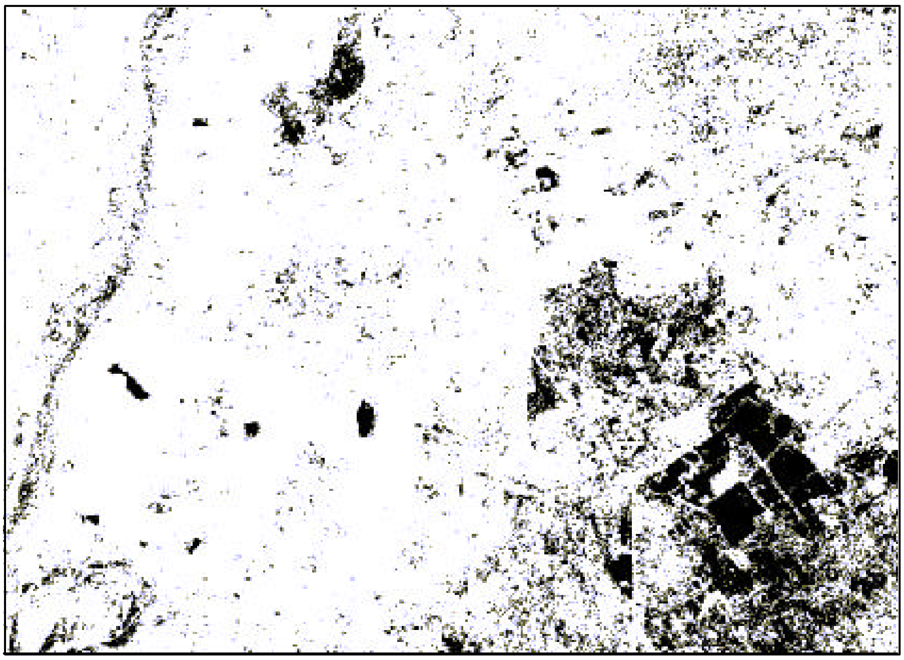


Fig. 5
Pixels found after PPI algorth as extreme (black colour points)

from each ASTER channel. Next the angle between the vectors is calculeted and the classifcation of a pixel is performed after comparing the value of calculated angle with the assumed limit value.

Endmember spectra used by SAM come from the image (selected in n-Dimensional Visualizer). SAM classification helps to identify sulphur pollution on the abandoned mines site.The range of the polluted area is so considerable, that with available ASTER data of resolution 15 and 30m we are able to distinguish this area, and, what is more, divide it into classes of different pollution intensity (Fig. 7).

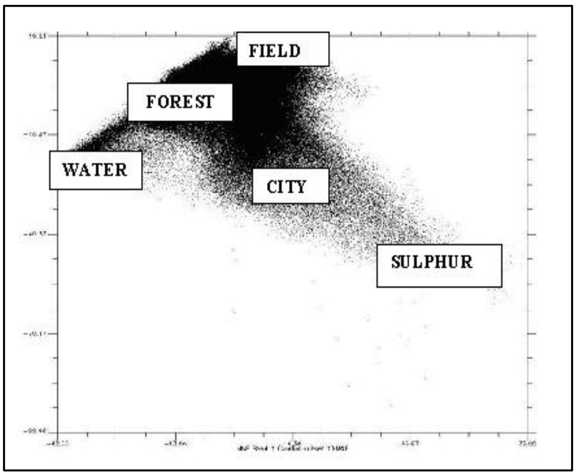


Fig. 6
Scatter Plot of 1 and 2 MNF bands with recognised types of land cover corresponding to the ASTER image

4. Conclusion

In this paper the results of hyperspectral/ multispectral data processing: spectral laboratory measurements and ASTER images processing were presented. All these analyses were made with the purpose of sulphur pollution determination, so only the area of sulphur mine site was classified. Other regions remain unclassified, and were masked during hyperspectral processing. The knowledge of the spectral characteristic changes in soil, caused by its pollution, would allow to implement remote sensing methods in soil degradation monitoring.

Generally, the research described were concentrated on 2 tasks:

- research of the influence of the sulphur content in the reference soil (sand) on its spectra,
- processing of multi/hyper spectral images to obtain the best diffraction of spectral

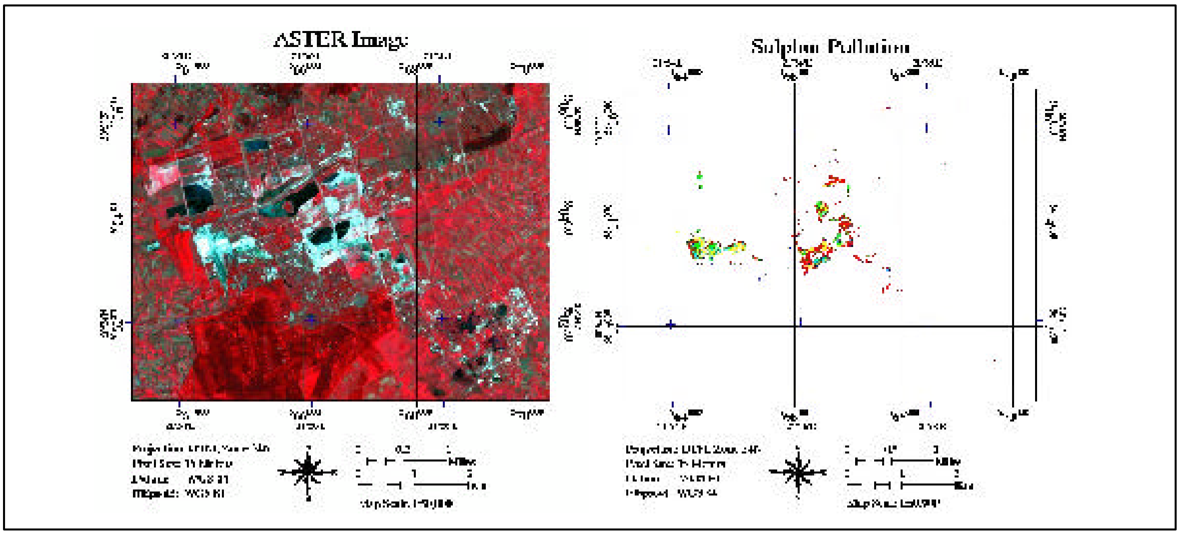


Fig. 7
False colour composit forASTER image before SAM (left side) SAM results for Jeziorko test area (right side)

information recorded in the image of Jeziorko mine site

In both cases promising results were obtained. The next step of our research is to combine the spectrometer data and airborne/ satellite images.

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