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A COMPARISON OF HYPERSPECTRAL AIRBORNE HYMAP AND SPACEBORNE HYPERION DATA AS TOOLS FOR STUDYING THE ENVIRONMENTAL IMPACT OF TALC MINING IN LAHNASLAMPI, NE FINLAND

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ABSTRACT

The MINEO project conducted in six mine sites in Europe demonstrated that image processing of airborne imaging spectrometry HyMap data offers an effective method for remote identification and characterization of environmentally relevant features in mining areas. HyMap data was previously used in MINEO context to classify environmental features of the Lahnaslampi talc mining area in Boreal environment, in Sotkamo, Finland. These resulting classes were validated in field or by other scientific methods.

The current study compares the hyperspectral HyMap data, which was recorded in July 2000 with EO-1 satellite borne Hyperion data, acquired 2 years 2 months later. The environmental impact on forest caused by mining impact is minor in the area and therefore the effort finding impact related signasl from the Hyperion data is a very challenging task.

The environmental targets/classes of this study are:

- Dust and seepage water affected areas in the Boreal forest.
- Areas of buffering minerals (in relation to acid mine drainage due to weathering of sulphide bearing wall rock)

The environmental targets had slightly changed between the recordings of these two sets of data. The most changed areas were removed before the main analysis and comparison. HyMap data can map environmental surface features such as contaminated vegetation, acid mine drainage, buffering minerals, features of vegetation stress and a few types of water suspensions.

This paper demonstrates a case to test correlation between HyMap and Hyperion bands and correlation between the environmental classes derived separately from these images. Hyperion data are noisier, but can, however, show outlines of the largest classes analogous to those extracted from HyMap data. The correlation coefficients computed between the HyMap and Hyperion overlapping channels are high outside the water absorption bands. The correlation coefficients between the environmental classes derived from the HyMap and Hyperion data are not too high, but because the number of samples is very high these correlations are relevant. Therefore the work is promising and worth continuing in optimal weather conditions.

INTRODUCTION

The Lahnaslampi talc mining test area (Figure 1) is located between the Kajaani and Sotkamo townships in NE Finland.

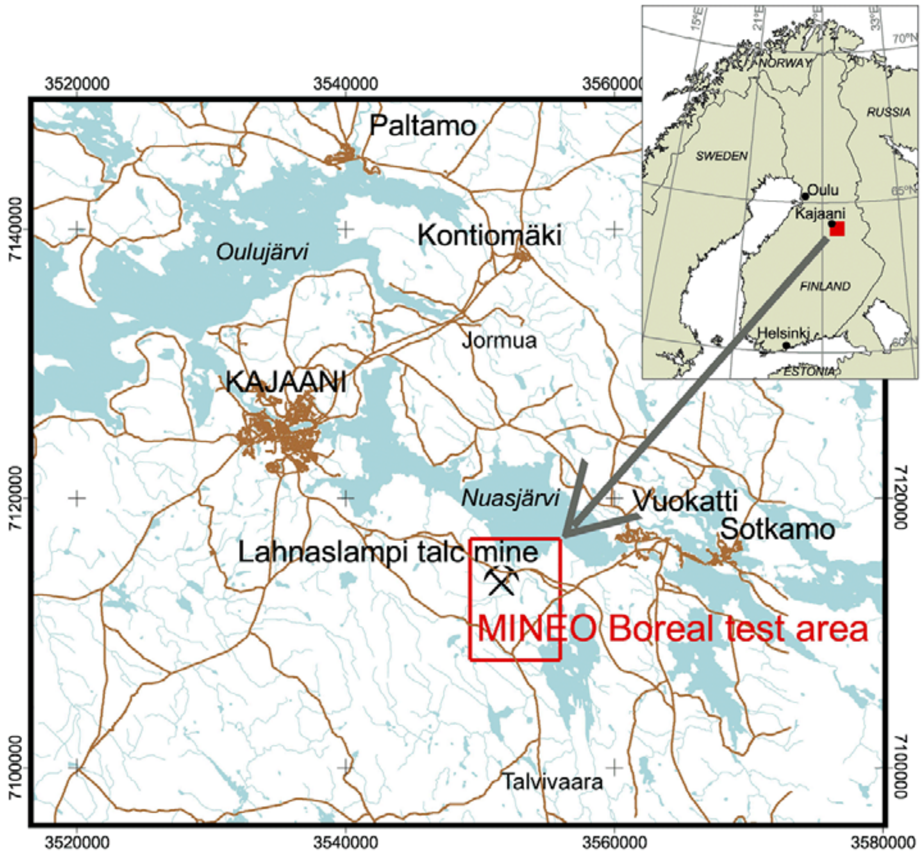

Figure 1 Geographic location of the Lahnaslampi test area.

The HyMap airborne scanning imaging spectrometer (i) provides 126 bands across the reflective solar wavelength region of 400 – 2500 nm with contiguous spectral coverage except in the atmospheric water vapour bands. The bandwidths (fwhm = full width at half maximum) are between 11 – 21 nm. The spatial configuration of the HyMap sensor is as follows.

- IFOV (Instantaneous Field-of-View) = 2.5 milliradians along track, 2.0 mrad across track
- FOV (Field-of-View) = 61.3 degrees (512 pixels)
- GIFOV (Ground-projected Instantaneous Field-Of-View) = 5.0 meters
- Swath width = 2.56 km

The EO-1 satellite borne Hyperion pushbroom imaging spectrometer (ii) provides 220 spectral bands across the reflective solar wavelength region of 400 – 2500 nm with contiguous spectral coverage, including the water vapour bands. The bandwidths (fwhm) are between 10 – 12 nm. The spatial configuration of the Hyperion sensor is following:

- IFOV= 0.043 mrad
- FOV = 0.63 degrees, across track
- GIFOV = 30.0 meters
- Swath width = 7.60 km

Figure 2 Color composite picture of visual (red, green and blue) channels of the HyMap airborne image data from the Lahnaslampi area. The open pit, enrichment plant, waste rock piles and the tailing ponds are visible. Pixel size is 5x5 $m^{2.}$ The training sites are marked by the coloured squares A, B and C. Width of the area is 4 km. Recorded on 28^{th} July 2000.

Figure 3 Color composite picture of visual (red, green and blue) channels of the Hyperion satellite data from the Lahnaslampi test area, the same as in the previous figure. The open pit, enrichment plant, waste rock piles and tailing ponds are visible. Pixel size is 30x30 m^2. Width of the area is 4 km. Recorded on 18^{th} September 2002.

The MINEO research (iii, iv) in six mining test areas in Europe has shown that airborne imaging spectrometry HyMap data (Figure 2) offers effective methods for remote identification and characterization of environmentally relevant surface features in mining environments. These features include minerals, which produce acid mine drainage often with high content of heavy metals, neutralizing minerals, dust, vegetation stress symptoms of various degrees, surface effects of seepage waters and siltation of drainage system. Those methods developed and tested by the MINEO projects may be used also in global context.

Therefore, the aim of the current work is to test whether the classification of hyperspectral EO-1 satellite Hyperion data (Figure 3) can reveal approximately the same environmental features as can be achieved using the HyMap data. This study compares the hyperspectral HyMap data, which was recorded on 28th July 2000 with EO-1 satellite Hyperion data, recorded 2 years 2 months later, on 18th September, 2002, in test area. The environment of the Lahnaslampi talc mine is a typical Boreal forest, growing mainly pine (Pinus sylvestris), spruce (Picea abies) and birch (Betula pendula and Betula pubenscens) on Pleistocene glacial soil cover over Precambrian bedrock. The environmental impact caused by mining in forest is very low in this area and therefore the effort to find an impact related signal from the Hyperion data is a very challenging task.

METHODS

Because the long time and seasonal difference between the recordings of HyMap and Hyperion images the environmental targets cannot be presumed to be spectrally equal. Trees are 'green' in HyMap imagery, but 'autumn colors' occur in Hyperion imagery. Therefore, use of global spectral libraries was impossible.

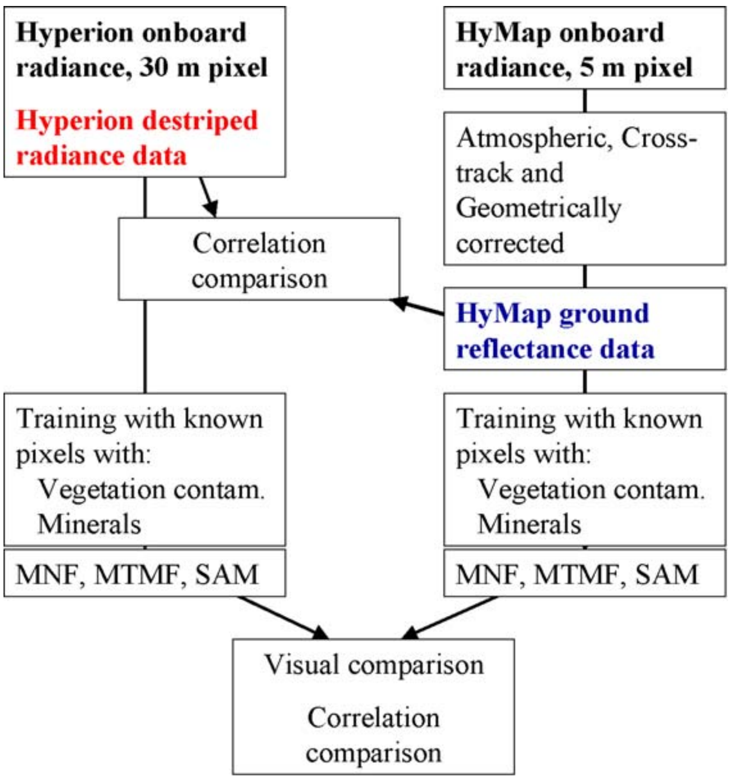

Figure 4 Flow chart of image processing and comparison. The acronyms are explained in the text.

Several pre-processing stages (Figure 4) were necessary both for Hyperion and HyMap data. The highly noisy channels, mostly in and around the water vapour absorption bands, were simply abandoned from both data sets, resulting in 122 HyMap and 147 Hyperion channels. Clouds were replaced by global mean in Hyperion data. Destriping was computed by balancing the mean and the standard deviation of adjacent columns to global mean and standard deviation. The HyMap on-board radiance was corrected for atmospheric, geometric and cross-track effects. The destriped Hyperion on-board radiance and HyMap ground reflectance were the 'final' corrected datasets used for their mutual comparison. Hyperion image was rebinned from original 30x30 m^2 pixels o 5x5 m^2 cell size.

The mutual comparison (Figure 4) was carried out by statistically comparing the overlapping parts of channels using band-by-band correlation coefficients. Both corrected datasets were classified by various methods, which are available in the ENVI software (v). The training sets were selected from spatially equivalent HyMap and from Hyperion pixels. The environmental classes from HyMap and Hyperion classifications were thereafter compared to each other using correlation coefficients and visual assessment.

RESULTS

Because the HyMap and Hyperion have different (Figure 5) configuration of channels, the overlapping parts of channels (Figure 6) were computed. Thereafter only channels overlapping more than 8 nm were used for the comparison.

Signal-to-noise ratio varies a lot from channel to channel both in HyMap and Hyperion data. Because of the limited size and lack of even targets in the area, the true signal to noise could not be computed, but a related parameter, shown in Figure 7 gives an idea of the relative S/N ratio of overlapping channels. This local parameter (= total land area mean divided by the water area standard deviation) is proportional to published S/N's (i), (ii) when multiplied by a factor 1.7.

Minimum Noise Fraction (MNF, v) components were computed for both HyMap and Hyperion (accepted) channels. The MNF eigenvalue (v) plot (Figure 8) shows that the noisy HyMap MNF components start from 20th and Hyperion from 10th component (see the x-value of the flattening point of the curves).

Only part of the environmental classes is demonstrated in this report. Selected known mineral and contaminated vegetation training sites were used for the supervised classification of HyMap and Hyperion images. The characteristics of the selected training sites are as follows:

A. Dust contaminated conifer forest (A in Figure 2)
B. Dust contaminated birch stands (B in Figure 2)
C. Exposed understorey vegetation with no trees, related to seepage waters or clear-cut, wet or dry areas (C in Figure 2)
D. Talc dominating site
E. Magnesite dominating site
F. Mica schist dominating site

Because classification of exposed mineral assemblages is not difficult, the current work demonstrates mainly the classes of contaminated vegetation (A, B and C).

The training sets were selected from same locations for HyMap and Hyperion data for the classifications. Mixed Tuned Matched Filtering (MTMF, v) was applied to the whole HyMap and Hyperion images with the training data taken from the MNF components (v) from the sites A, B and C (in Figure 2). However, the Spectral Angle Mapping (SAM, v) of the HyMap and Hyperion data with the same training sites resulted in more concise classes showing prominent coincidence (Figure 9 and Figure 10) between HyMap and Hyperion classes.

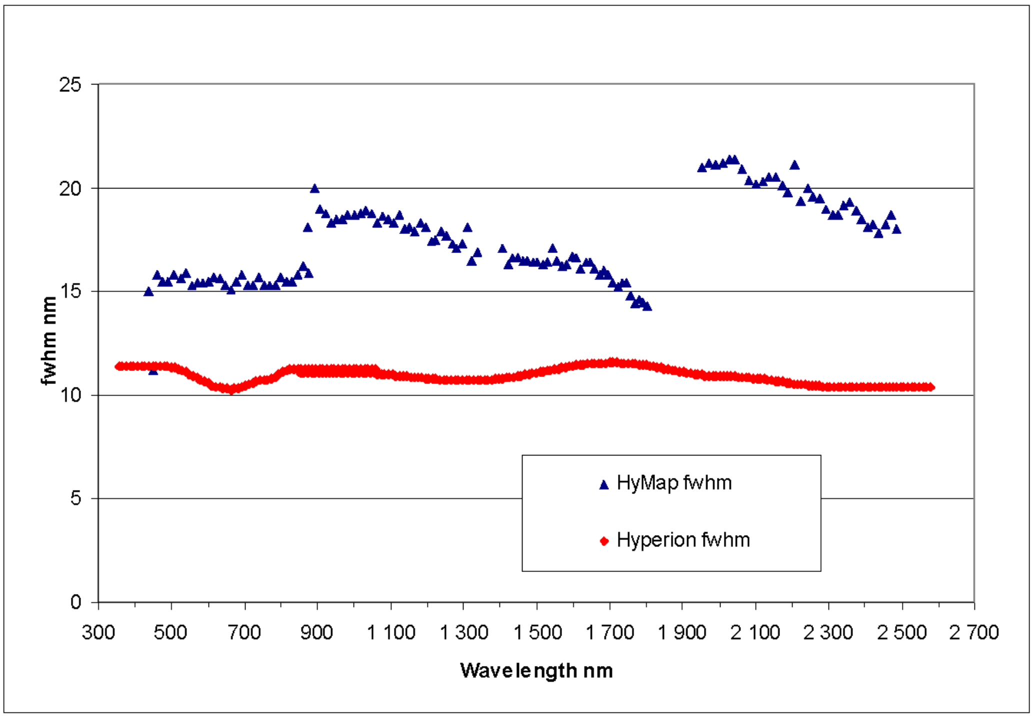

Figure 5 Widths of the current HyMap and Hyperion image channels as fwhm's [nm].

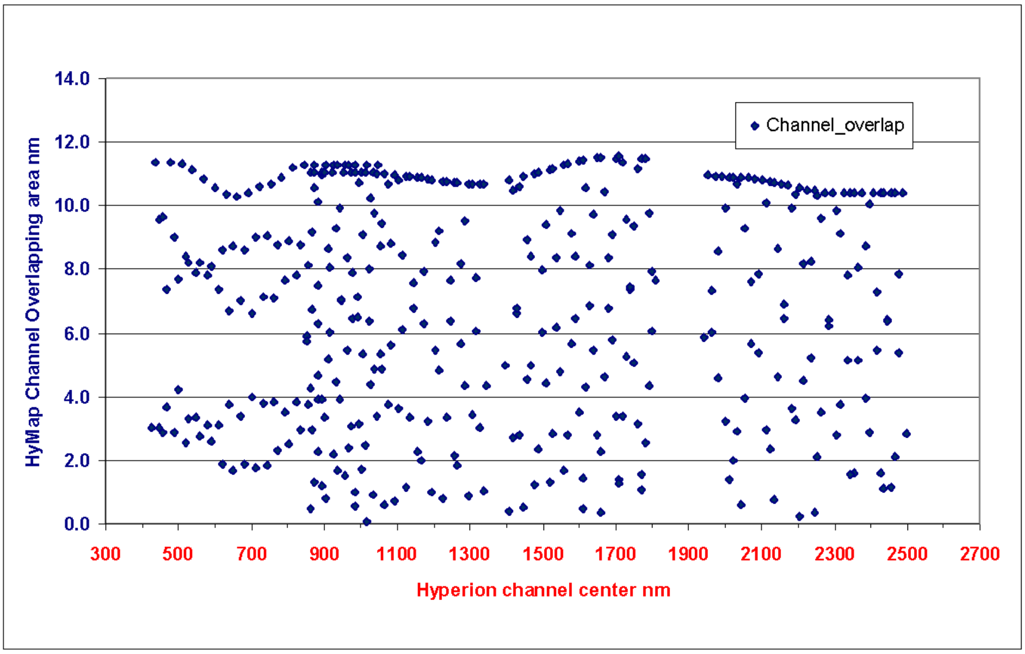

Figure 6 Spectral overlap of the current HyMap and Hyperion image channels as fwhm's [nm].

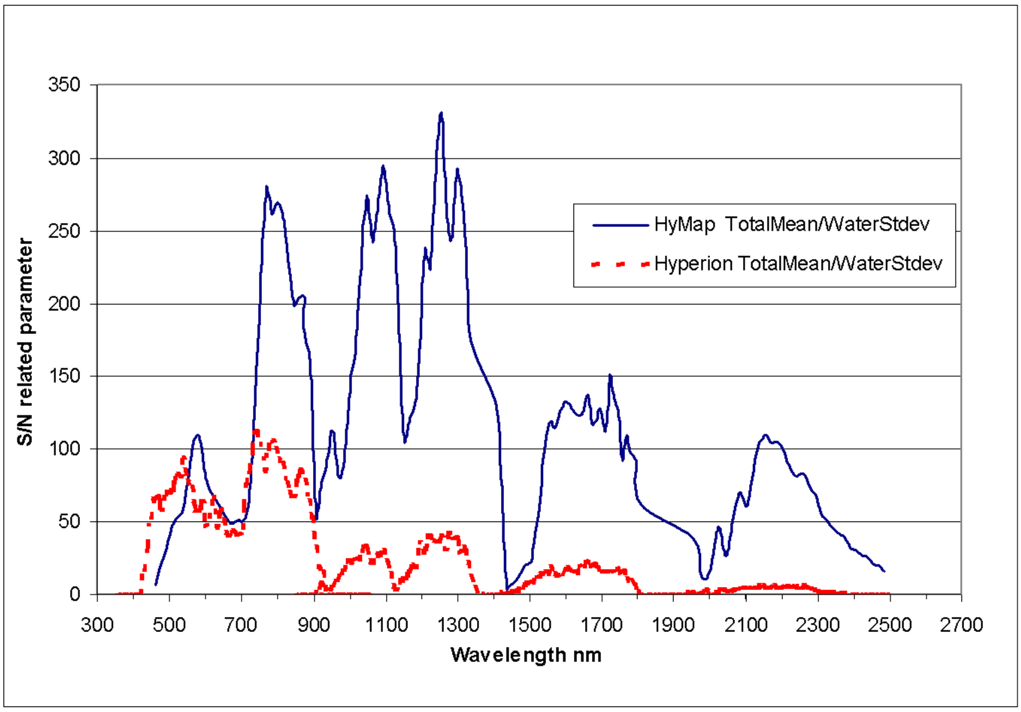

Figure 7 HyMap and Hyperion total Mean divided by the Standard Deviation of water area of the test site. This local parameter is proportional to published S/N when multiplied by a factor 1.7.

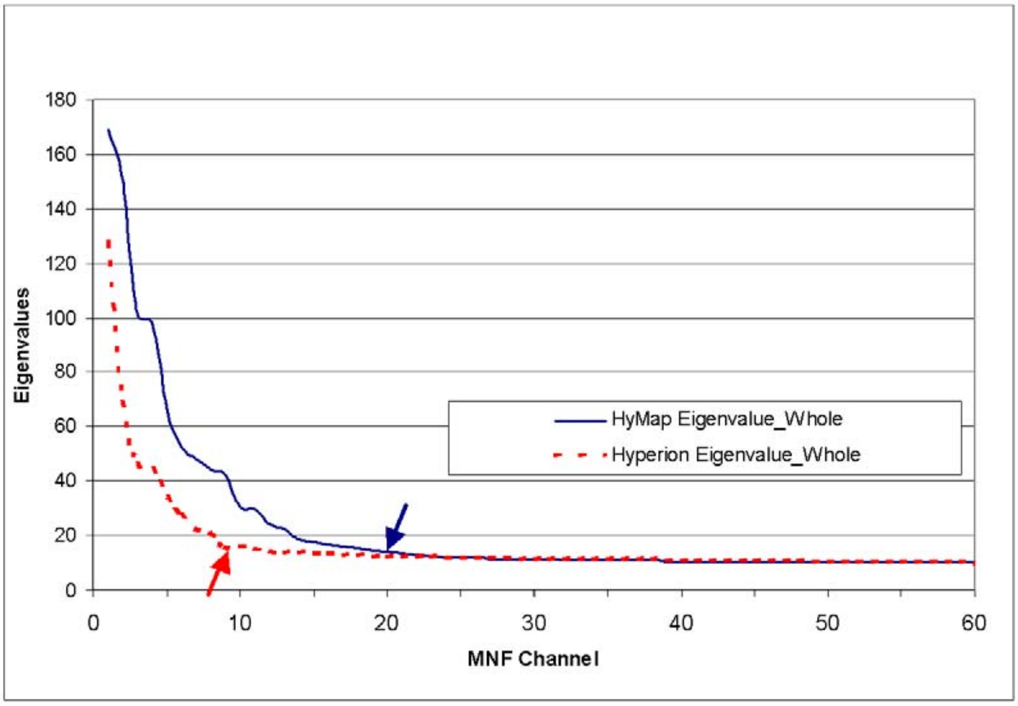

Figure 8 HyMap and Hyperion Minimum Noise Fraction (MNF) Eigenvalues scaled on the same noise level. The noisy HyMap MNF components start from 20th and noisy Hyperion from 8th component.

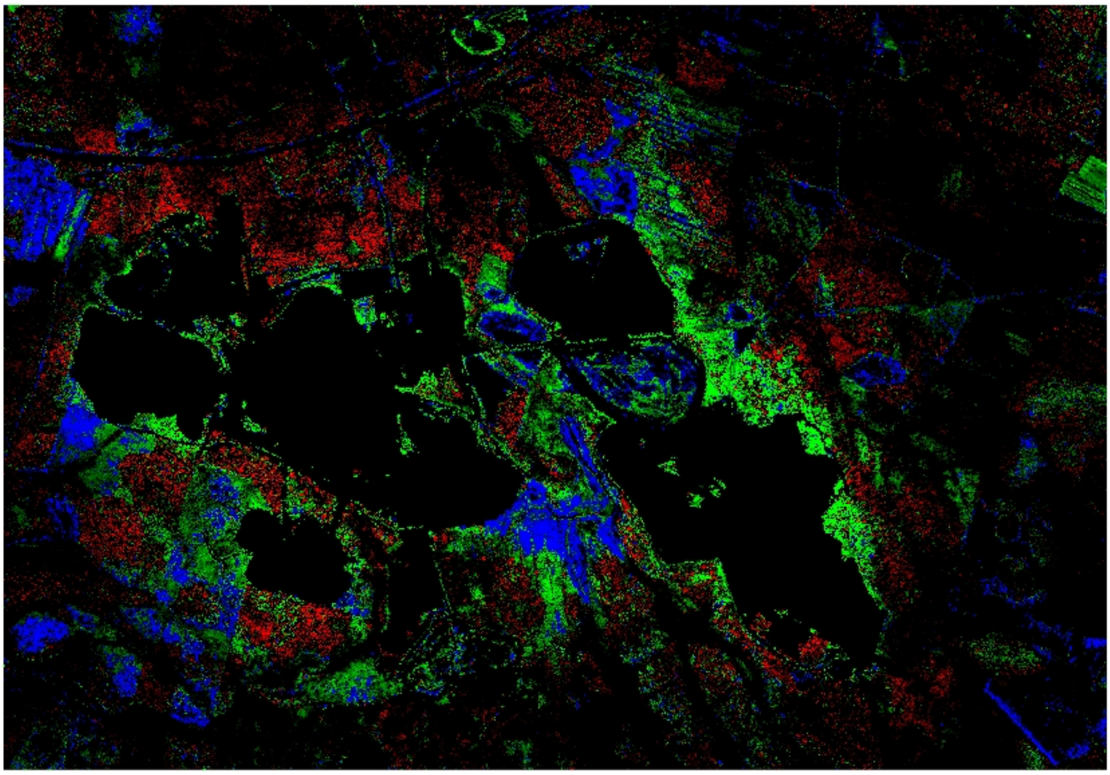

Figure 9 Environmentally related vegetation classes interpreted from HyMap data in the test area. The class colors red, green and blue refer to the SAM classes by training sites A, B and C respectively (see Table).

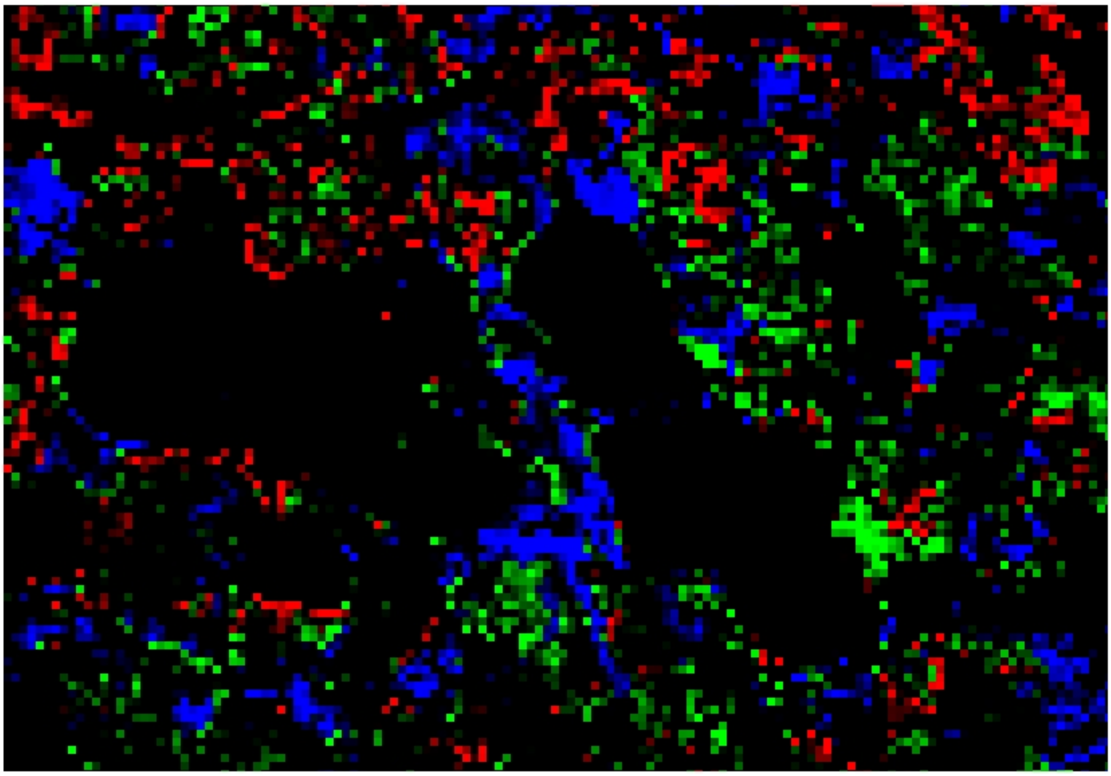

Figure 10 Environmentally related vegetation classes interpreted from Hyperion data in the test area. The class colors red, green and blue refer to the SAM classes by training sites A, B and C respectively (see Table).

Correlation coefficients between the inversed rule images for the environmental classes derived from the HyMap and Hyperion data are not too high (Table 1). However, because the number of samples is very high (2 x 235 270 pixels in computing the coefficients) these correlations are statistically significant ($p < 10^{-6}$).

Table 1 Correlation coefficients computed between SAM rule channels from HyMap and Hyperion data.

	Class training See the list on p 353	Model	Correlation coefficient
Environmental vegetation classes	A	SAM Contam conifer	0.472
	B	SAM Contam birch	0.432
	C	SAM Understorey, no trees	0.374
Mineral classes	D	SAM Talc	0.599
	E	SAM Magnesite	0.569
	F	SAM Mica schist	0.539

The SAM classification, trained by the mineral sites (D, E and F), resulted in rule images which show clear correlation (Table 1) between HyMap and Hyperion classes concerning talc, magnesite and mica schist dominating sites in the Lahnaslampi test area.

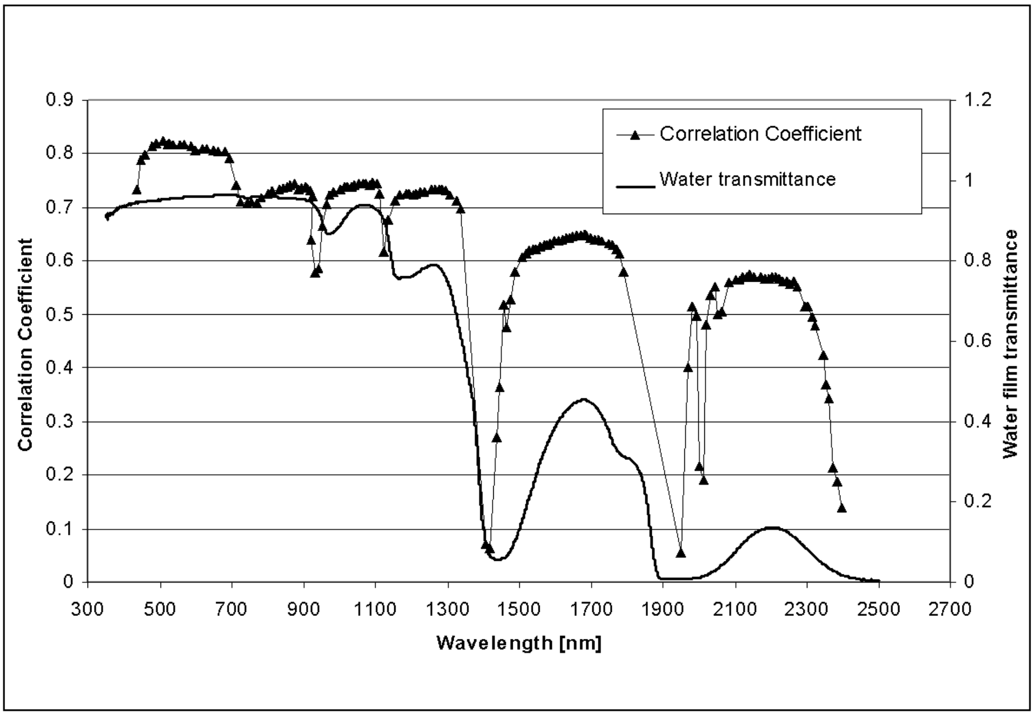

Figure 11 Correlation coefficients between the HyMap and Hyperion overlapping channels. Water thin film transmittance curve is shown for comparison.

The correlation coefficients computed between the HyMap and Hyperion overlapping channels show a clear tendency (Figure 11). Correlation is high in the areas with less noise caused by water absorption bands (correlation is naturally dependent also on the sensor targeting design). When the correlation coefficients of the environmental features in Table are compared to the band-by-band correlation in Figure 11, the former are much lower. The reason for this is that the band-by-band correlation varies with general albedo, but the environmental features are formed actually by small spectral anomalies on albedo.

CONCLUSIONS AND DISCUSSION

Kruse (vi) compared the ability of Hyperion and AVIRIS data to map mineralogy in Cuprite, Nevada. He concludes that in summer conditions Hyperion data classification works well, but when the data are collected under less than optimum conditions (winter season, dark targets) have marginal SWIR S/N and allow mapping of only the most basic mineral occurrences and mineral differences.

The aim of the current work was to test whether the classification of hyperspectral EO-1 satellite Hyperion data (Figure 3) can reveal approximately the same environmental features from the Lahnaslampi talc mining environment as can be achieved using the HyMap data. The environmental stress caused by mining impact in forest is very low in this test area.

The environmental targets had slightly changed between the recordings of these two sets of data, but the temporally most changed areas were removed before the main analysis and comparison. Systematic noise was reduced from the Hyperion data. After supervised classification the resulting environmental classes from HyMap and Hyperion classifications were thereafter compared to each other.

HyMap data can map contaminated vegetation, acid mine drainage producing and buffering minerals. Hyperion data are much noisier, but can, however, show up outlines of the largest environmental analogous classes. Correlation coefficients between the HyMap and Hyperion overlapping channels are systematically high. But, correlation coefficients between the rule images for the environmental classes derived from the HyMap and Hyperion data are not too high. There are several reasons for this: Temporal changes between the two recordings do occur and the environmental features are not spectrally equal in HyMap and Hyperion data. The atmospheric conditions were not optimal for Hyperion recordings in this case. Further, the environmental features are only small spectral anomalies on albedo variation in both datasets. Because the number of samples is very high, the correlations obtained are statistically significant. The work is promising and worth continuing in optimal weather conditions.

ACKNOWLEDGEMENTS

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