Monitoring Norway spruce forest conditions using hyperspectral data

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Project team for hyperspectral studies on Norway spruce:

- **Faculty of Science Charles University in Prague**

  PI: Dr. Jana Albrechtová, Dr. Zuzana Lhotáková, Dr. Lucie Kupková, Dr. Markéta Potůčková, Mgr. Lucie Červená, Mgr. Monika Kovářová

- **Czech Geological Survey**

  Mgr. Veronika Kopačková, Mgr. Jan Mišurec

- **University of Maryland, JCET NASA GSFC**

  Dr. Petya Entcheva-Campbell

3 hyperspectral studies in NW Bohemia

1. **NASA (1997-2000)**
2. **INMON (2012-2014)**
3. **HyPSO (2009-2012)**

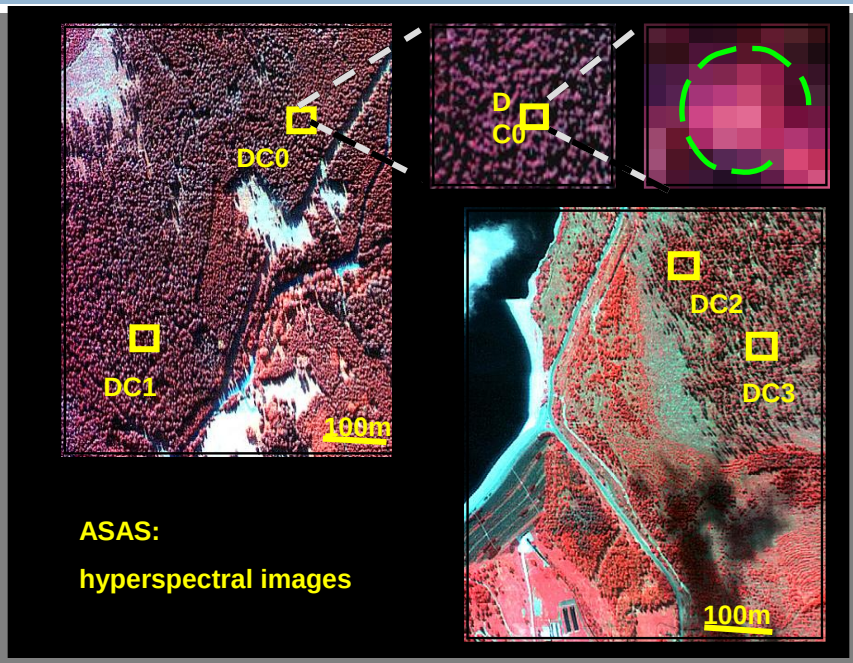
NASA et INMON Projects (1997-2000, 2012-2014) Region of Interest : North-Western Bohemia, the Krusne hory Mts.

1. NASA Project 1997-2000: Campaign 1998

Follow up research of forest ecosystems health from the 1990‘s:
NASA project „Forest recovery in the Czech Republic“ NAG5-5192 (CFDA #43.002), **(1997-2000),** UNH, Complex Research Systems Centre, USA,
PI: Barrett N. Rock, UNH

Flight Campaign 1998

Sensor: Airborne Solid-state Array Spectroradiometer (ASAS) NASA Goddard Space Flight Center, USA.



Detection of previsible damage stages (DC0 a DC1):

Optical indices: C1, RE1 and RARSc

Derivative indices: D714/D704 and Dmax/D704

Inverted Gaussian model (IGM)

•*Albrechtová J, Rock BN, Soukupová J, Entcheva P, Šolcová B, Polák T. Biochemical, histochemical, structural and reflectance markers of damage in Norway spruce from the Krušné hory used for interpretation of remote sensing data. Journal of Forest Science, 2001, 47, (Special issue), p. 26-33*

Goals in 1998

The primary goal of this research is to assess the potential of airborne and field based high spectral resolution remote sensing and narrow band multispectral technology for separation of initial levels of forest damage.

•Document the extent of the changes in forest stand parameters, foliar pigments, chemistry and spectral signatures occurring with damage in Norway spruce foliage;

•Evaluate the potential of airborne hyperspectral remote sensing for separation of the initial level of damage in the Norway spruce canopies from the Krusne hory.

1. NASA Project 1997-2000: Campaign 1998

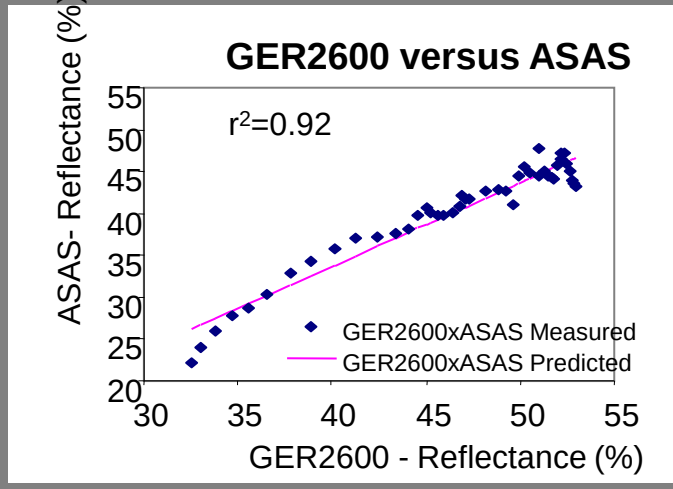
Antonov AN-2 single engine biplane

ASAS on board of AN2

For this study ASAS was flown on-board an Antonov AN-2, single engine biplane, at 2500m above the terrain, resulting in approximately 820m swath width and slightly rectangular pixels at 1.5x2.00m nominal ground resolution.

Flight Parameters	ASAS Specifications
Flight Altitude	2500m
Swath Width	820m
Side overlap of flight lines	20%
Nominal spatial resolution	~2m
Number of Bands	62 (45)
Spectral Region	500-850nm

Flight attributes for ASAS nadir data acquisition, Czech 1998



1. NASA Project 1997-2000: Campaign 1998

1998 Conclusions

- The study demonstrates a strong correlation between damage level and foliar chemistry. A significant increase in polar compounds and a reduction in lignification occurred with increasing damage level. Foliar chemical compounds appeared to be effective indicators of long-term environmental conditions.

- Hyperspectral data provide capabilities for separation of initial forest damage classes (DC0 and DC1), not provided by the broad-band multispectral data.

- Seven ASAS indices were identified as providing the most potential for use as indicators of the initial level of damage: four optical and tree derivative indices using reflectance from the red region (sensitive to F) to green or far-red (not sensitive to F).

- The spectral changes in canopy reflectance indices were explained primarily by the changes in the foliar chemical compounds, providing the bio-physiological link for use of the spectral indices as indicators of forest damage.

1. NASA Project : Field Campaign 1998

Czech 1998 Field Team: 1. Dr. Barrett Rock, University of New Hampshire; 2. Jitka Bilkova, Charles Univeristy CU; 3. Dr. Jana Albrechtova, CU; 4. Blanka Solcova, CU; 5. Ryan Huntley, UNH; 6. Petya Entcheva, UNH; 7. Shannon Spencer, UNH; 8. Ales Soukup, CU; 9. Anja Wothington, UNH; 10. Radka Malcova, CU; 11. Sarah Pope, UNH; 12. Dr. Richard Miller, NASA Stennis Space Center

2. INMON - Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data (2012-2014)

- Project team:
  - **Faculty of Science Charles University in Prague**

    PI: Dr. Jana Albrechtová, Dr. Zuzana Lhotáková, Dr. Lucie Kupková, Dr. Markéta Potůčková, Mgr. Lucie Červená, Mgr. Monika Kovářová
  - **Czech Geological Survey**

    Mgr. Veronika Kopačková, Mgr. Jan Mišurec
  - **University of Maryland**

    Dr. Petya Entcheva-Campbell

- Duration: **2012 – 2015**, data acquisition summer 2013

- The research is focused on so called Black triangle area (Krusne hory Mountains), aims to follow up research of forest ecosystems health from 1990‘s (ASAS data) - to evaluate development of ecosystems damaged by air pollution

2. INMON - Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data (2012-2014)

- **Project goals**
  - Evaluation of current health status of selected Norway spruce stands in the Krusne hory Mts. using biochemical foliage composition, spectral property (mainly reflectance) and aerial hyperspectral data.
  - Linking foliage chemical composition and spectral properties with soil chemical properties (basic cations, heavy metals, pH,C/N, DOC, DON, etc.).
  - Adjustment of methodology for processing of hyperspectral data to allow comparison of health status of Norway spruce stands in the Krusne hory Mts. in the end of the 1990´s (data obtained by sensor ASAS from Goddard Space Flight Center and processed by Dr. Entcheva-Campbell) and in the present.

2. INMON - Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data (2012-2014)

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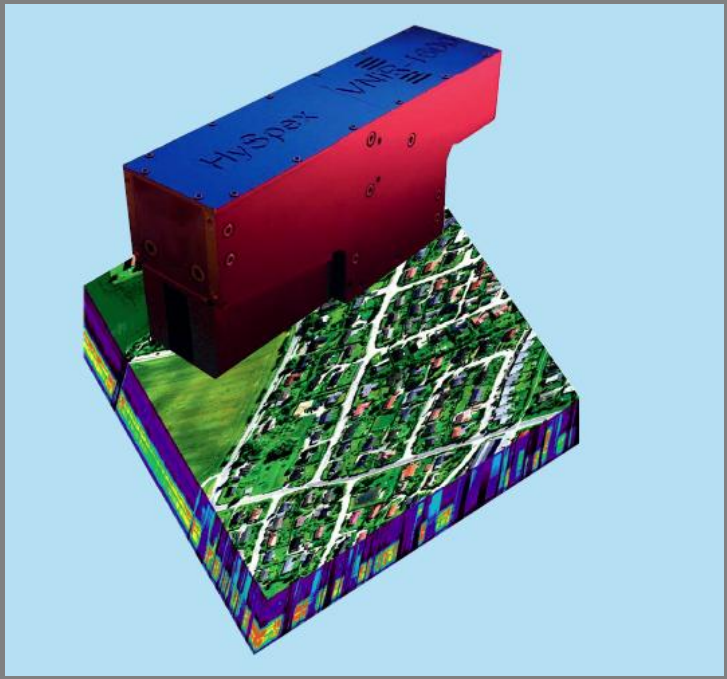
Field campaign 2013

- **Data and methods:**
  - Airborne hyperspectral imagery
    - HySpex: 0.44-2.50 µm (2013)
  - Field measurements and sampling
    - Foliar pigments (chlorophyll, carotenoids, lignin, cellulose, water etc.)
    - Spectral properties of needles (ASD Fieldspec-4 + integration sphere)
    - Soil samples (pH, heavy metals, bazic cations, trace elements, DOC, DON)
    - LAI measurements (hemispherical photography)
    - Defoliation assessment

2. INMON - Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data (2012-2014)

HySpex sensor characteristics, DLR



	HySpex	
Parameters	VNIR	SWIR
FOV (°)	17	13.5
Min. Ground resolution (m)	0.3	0.6
N. of channels	160	256
Spectral range (nm)	440-990	970-2500
Spectral band width	3.7	6.25

3. Hypso: Hyperspectral Sokolov (2009-2013)

- **Primary Investigator:**
  - **Czech Geological Survey** – Veronika Kopačková (CGS)
  - **Co-Investigator:**
  - **Faculty of Science Charles University in Prague** – Dr. Jana Albrechtová, Dr. Zuzana Lhotáková, Dr. Lucie Kupková, Dr. Markéta Potůčková
  - **Global Change Research Centre** – Ing. Jan

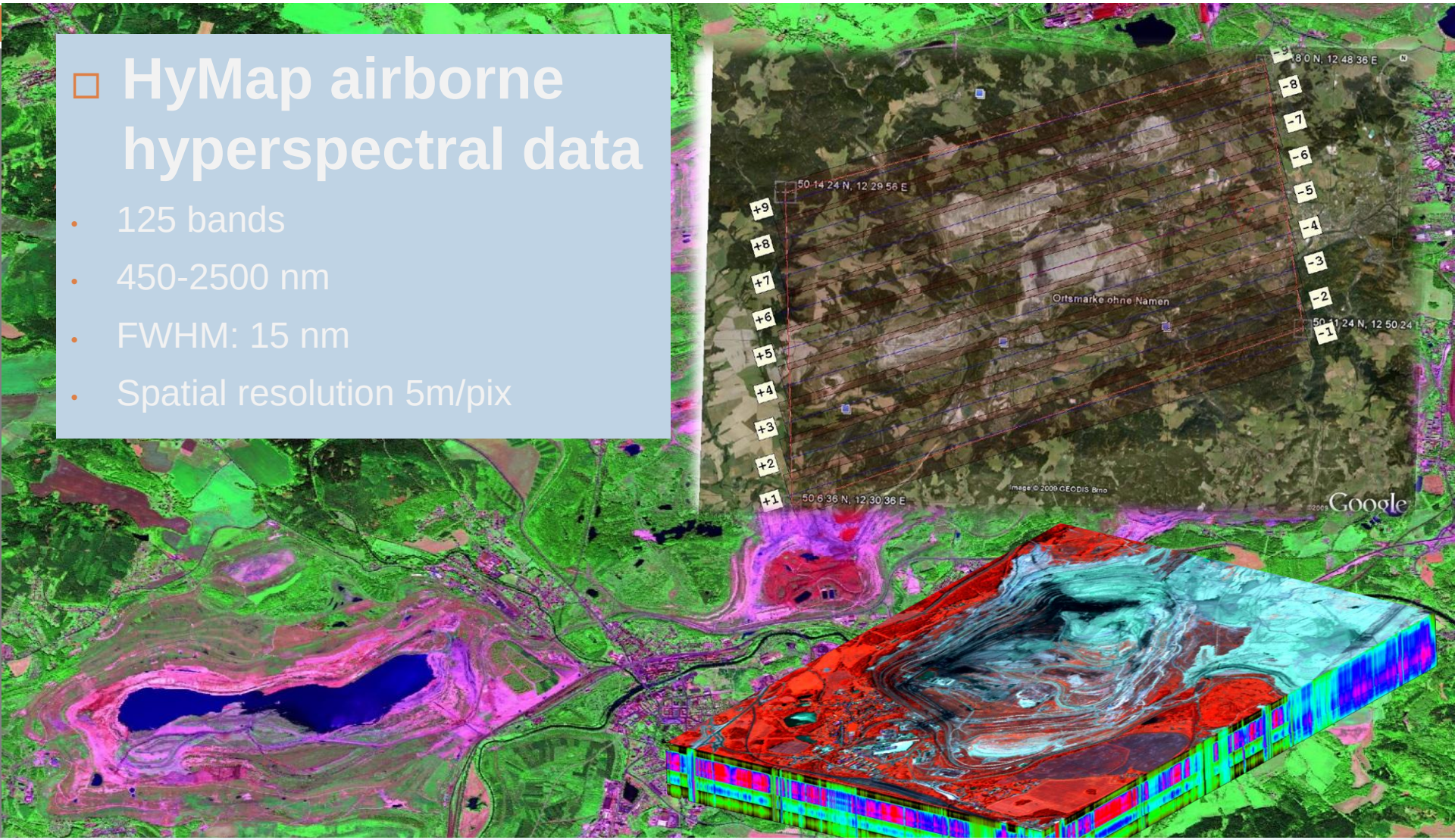
- **Test site:**
  - Sokolov lignite basin
  - Western part of the Czech republic
  - Affected by long-term coal mining

3. Hypso: Hyperspectral Sokolov (2009-2012)

Main goals and objectives

1. Improving capabilities of HS imagery processing approaches applied to areas heavily affected by long term mining activities.
2. Mineral mapping and geochemical modeling
3. Mapping of the curent extend of the areas affected by mining activities (tailing pounds, acid and heavy metal polluted areas, spoil heaps etc.)
4. Vegetation health assessment (health conditions and health status of forest stands surrounding the mines and pioneer vegetation)

3. HyPSO: Sokolov : HyMap data 2009 and 2010



- **HyMap airborne hyperspectral data**
  - 125 bands
  - 450-2500 nm
  - FWHM: 15 nm
  - Spatial resolution 5m/pix

3. HyPSO: Sokolov field data, ground truth

- **Field measurements and sampling**
  - ASD FieldSpec-3
    - In-situ spectroscopic measurements (0.350-2.500 μm)
  - Samples of surface material (0-1 cm depth)
    - Dried and sieved (<2 mm)
    - Trace elements, heavy metals, XRD analysis, pH, sulfur, total organic carbon (TOC)
  - Soil probes
    - Heavy and alkali metals, carbon, sulfur, pH, trace elements
  - Vegetation samples
    - Leaf pigments , water content, heavy metals, trace elements etc.
  - Water samples
    - pH, dissolved organic matter, conductivity, suspension

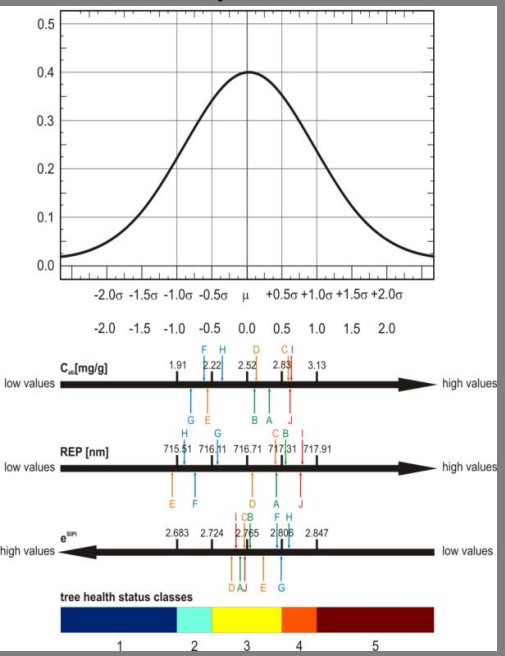
OBIA

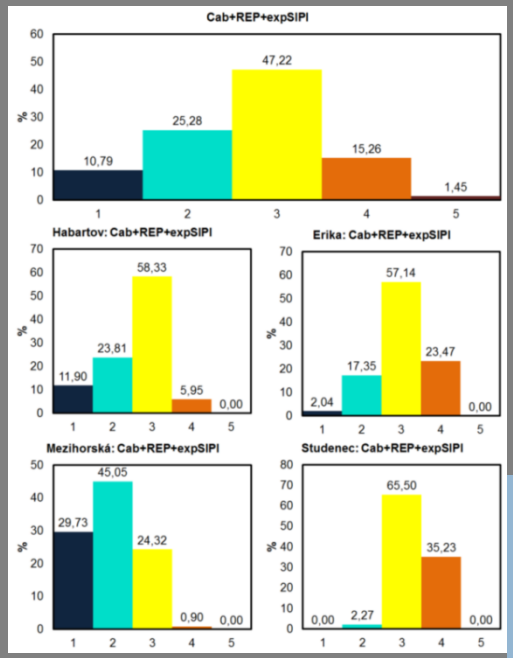
3. HyPSO: Sokolov Forest health assessment

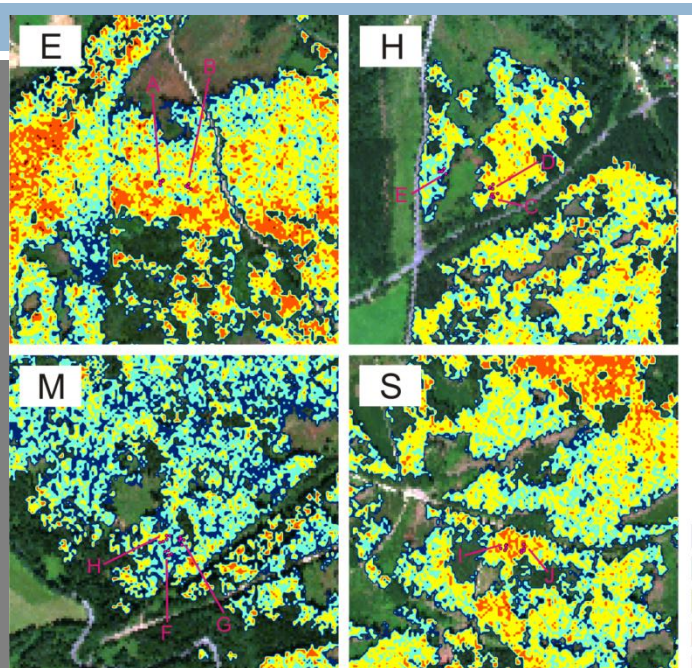
3. HyPSO: Forest health assessment 2009

- **Norway spruce health status classification**

- Integration of the derived C_{ab} content with other vegetation indices: REP and SIPI
- Statistical classification method
- Asymmetries of the health class frequencies at the studied sites



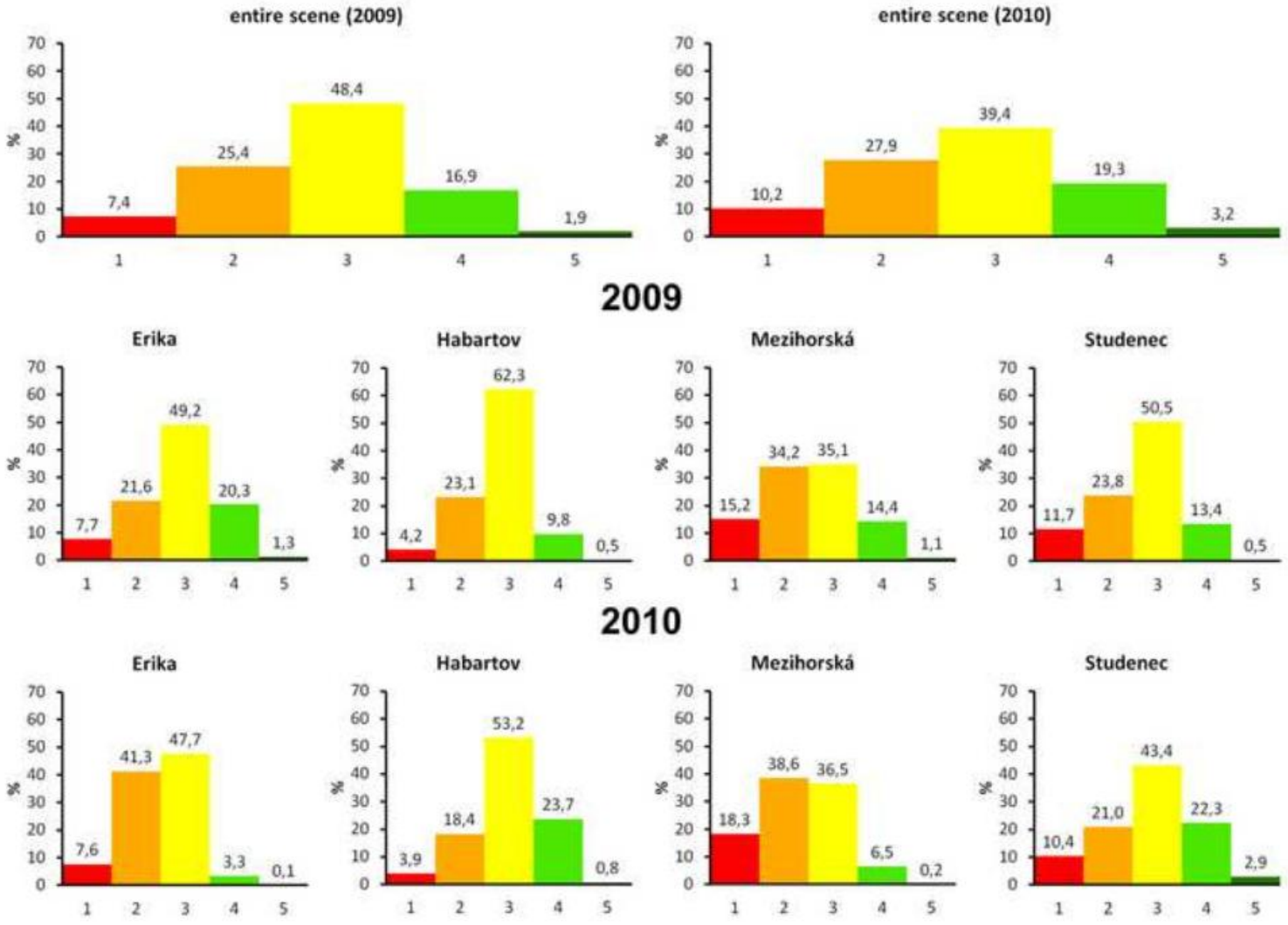




Health status classes for the trees without visual damage symptoms
1 - the worst and 5 - the best result

MIŠUREC, J., and KOPAČKOVÁ, V., LHOTÁKOVÁ, Z., HANUŠ, J., WEYERMANN, J., ENTCHEVA-CAMPBELL, P., ALBRECHTOVÁ, J., 2012: Utilization of hyperspectral image optical indices to assess the Norway spruce forest health status, Journal of Applied Remote Sensing, vol. 6, 1-25

3. HyPSO: Forest health assessment 2009 and 2010

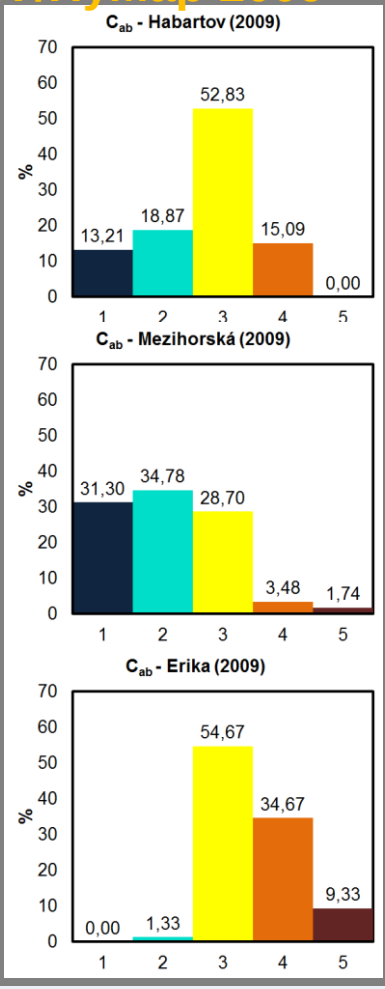


- Kopačková, V., Lhotáková, Z., Oulehle, F., Albrechtová, J., (under review): Assessing forest health via linking the geochemical properties of a soil profile with the biochemical vegetation parameters, International Journal of Environmental Science and Technology.

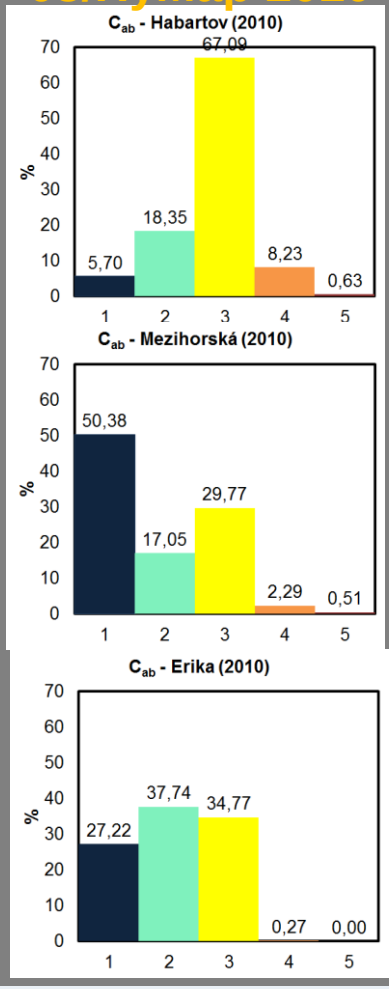
3. HyPSO: Forest health assessment 2009 and 2010

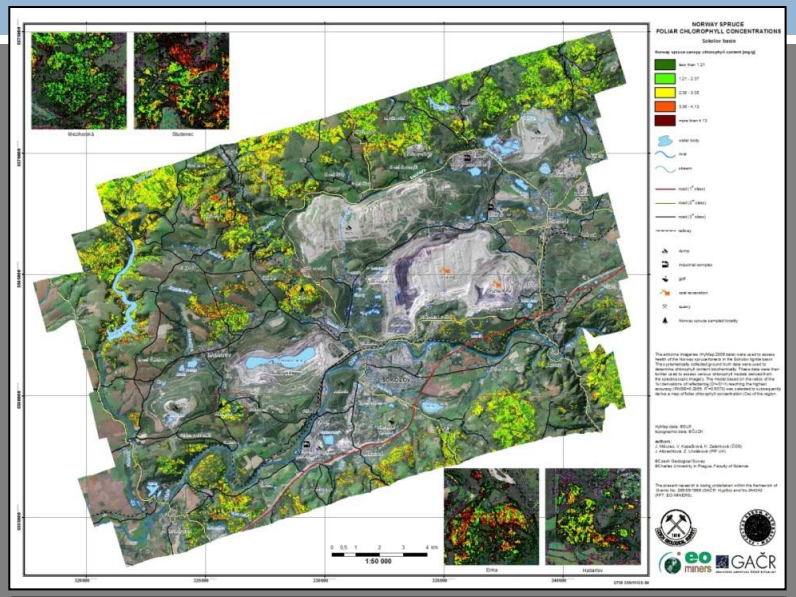
Validation of the developed methods

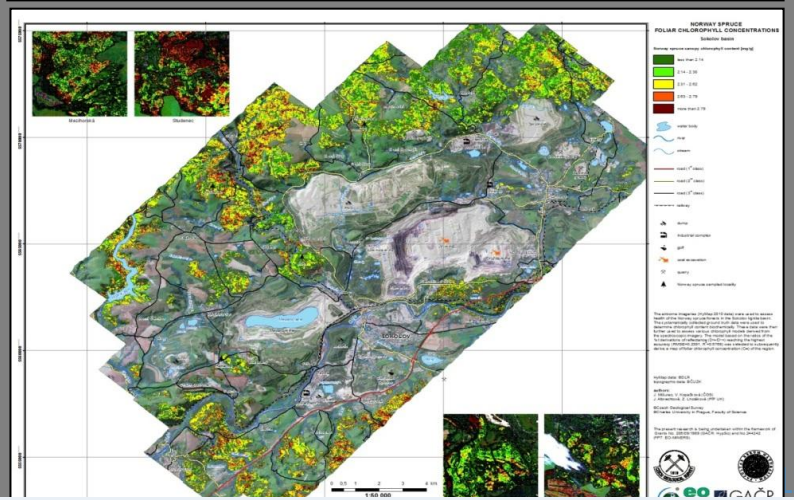
07/HyMap 2009



08/HyMap 2010

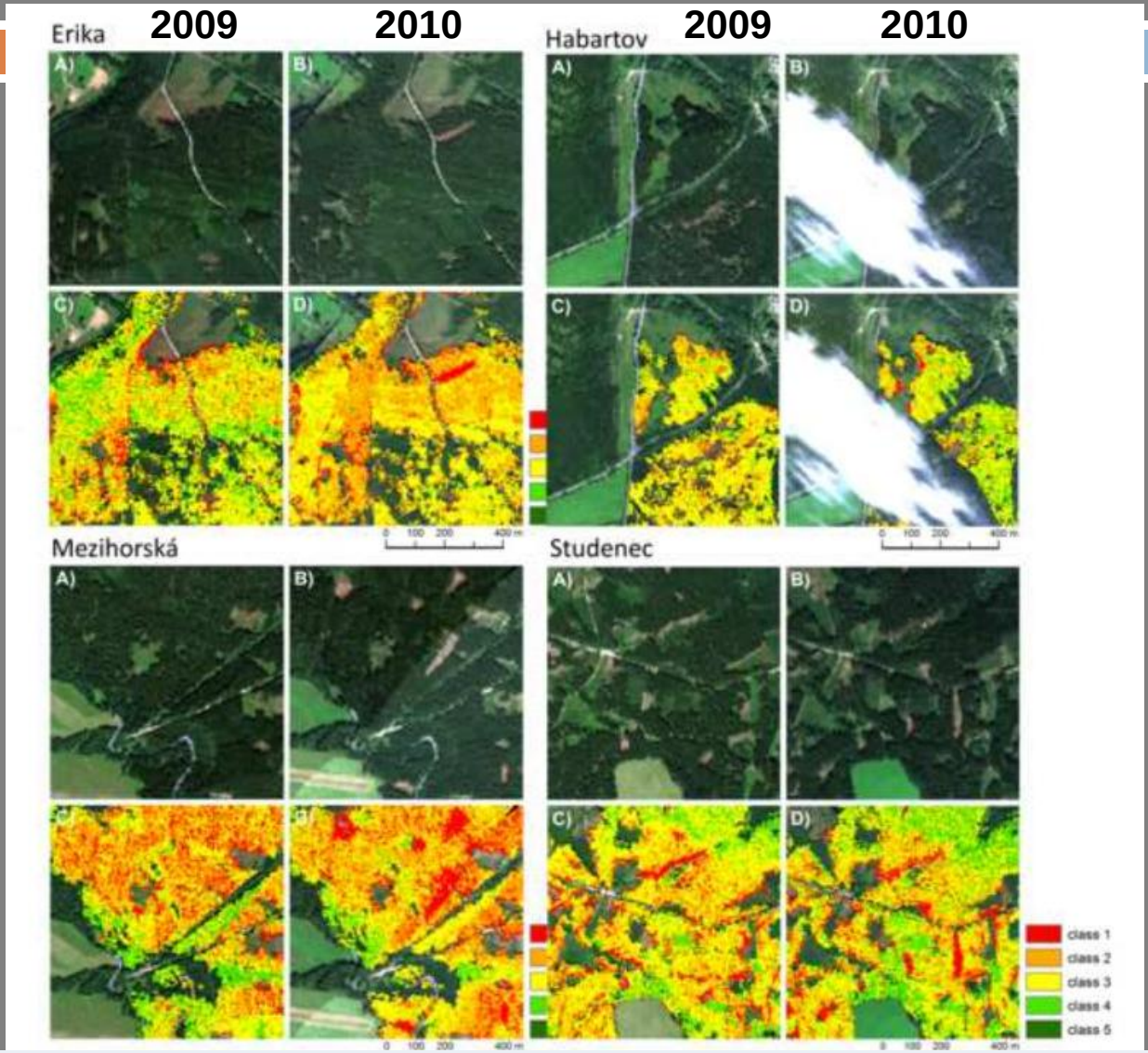






3. HyPSO: Forest health assessment 2009 and 2010

Forest health assessment 2010



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Thank you for your attention !

Acknowledgement

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University of New Hampshire: Barrett N. Rock