Hyperspectral datasets for monitoring tree physiological status – projects in the Western part of the Czech Republic (Black Triangle)

Jana Albrechtova, Lucie Kupkova

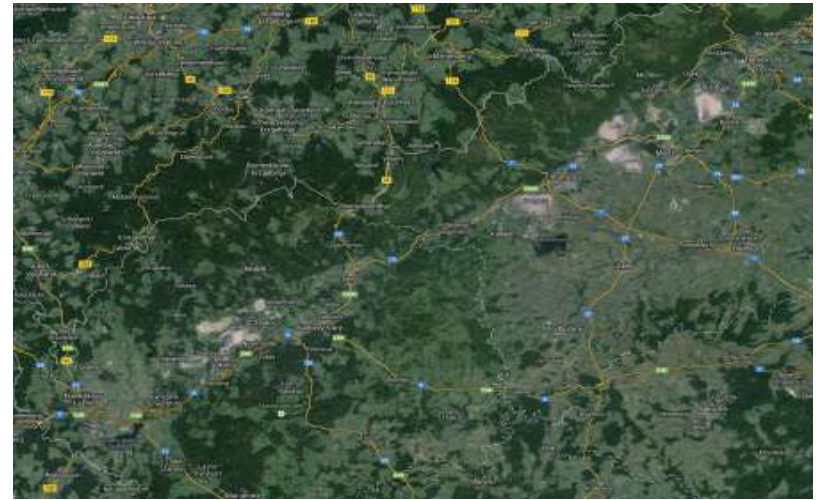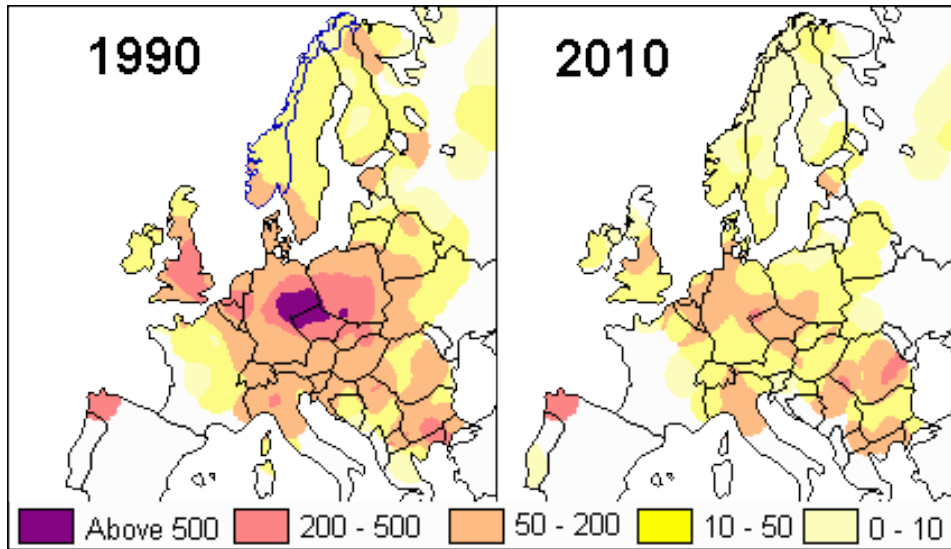Faculty of Science
Charles University Prague, Czech Republic,
1-Department of Experimental Plant Biology, albrecht@natur.cuni.cz,
2-Department of Applied Geoinformatics and Cartography, lucie.kupkova@gmail.com
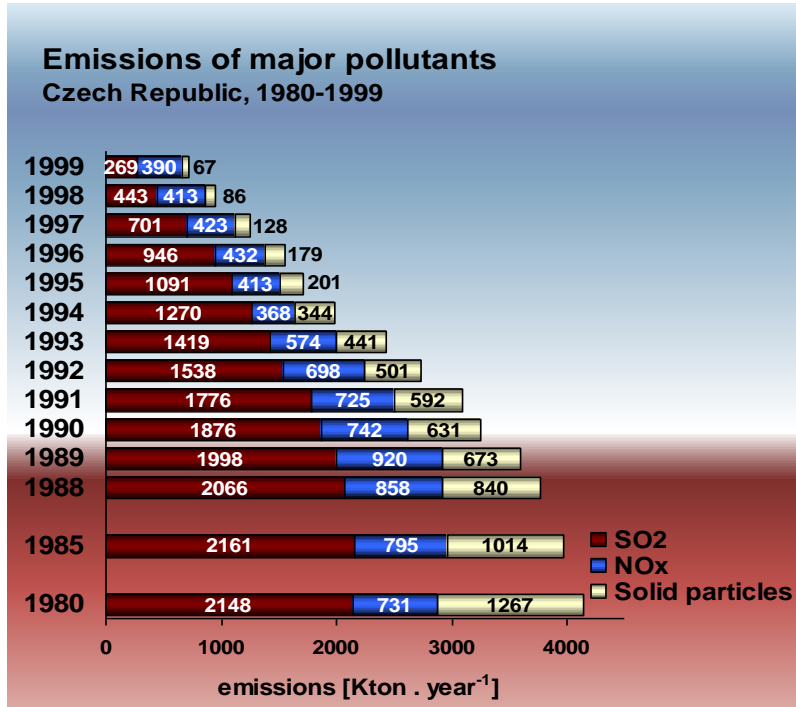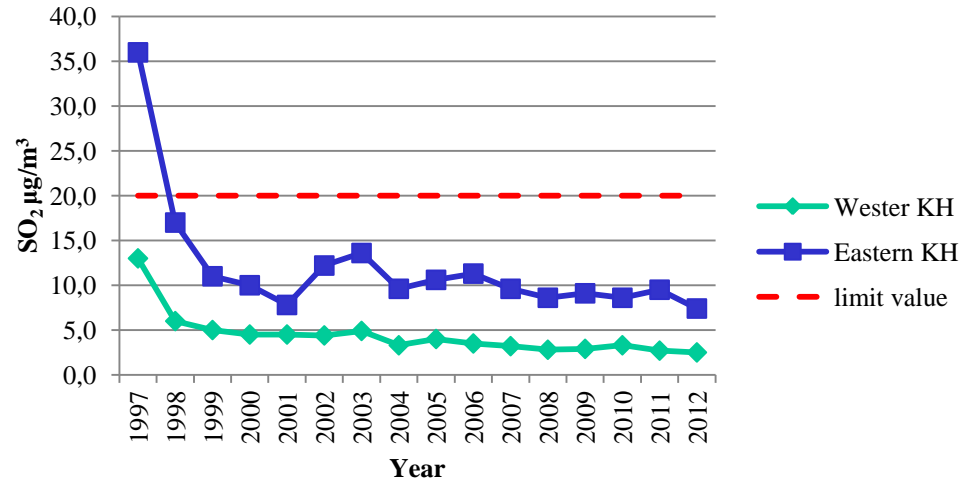
Black Triangle in Europe

SO$_2$ in Europe (Tons per km2)

Black Triangle in CZ: forests in mountains, strip mines, reclamation sites

Emissions of major pollutants
Czech Republic, 1980-1999

Year	SO2	NOx	Solid particles
1999	269	390	67
1998	443	413	86
1997	701	423	128
1996	946	432	179
1995	1091	413	201
1994	1270	368	344
1993	1419	574	441
1992	1538	698	501
1991	1776	725	592
1990	1876	742	631
1989	1998	920	673
1988	2066	858	840
1985	2161	795	1014
1980	2148	731	1267

emissions [Kton . year^{-1}]

Air SO$_2$ concentrations 1997 - 2012

$SO_2 \mu g/m^3$

- Wester KH
- Eastern KH
- — limit value

Year

The 1970-1990´s: dead forests in the Krusne hory Mts.

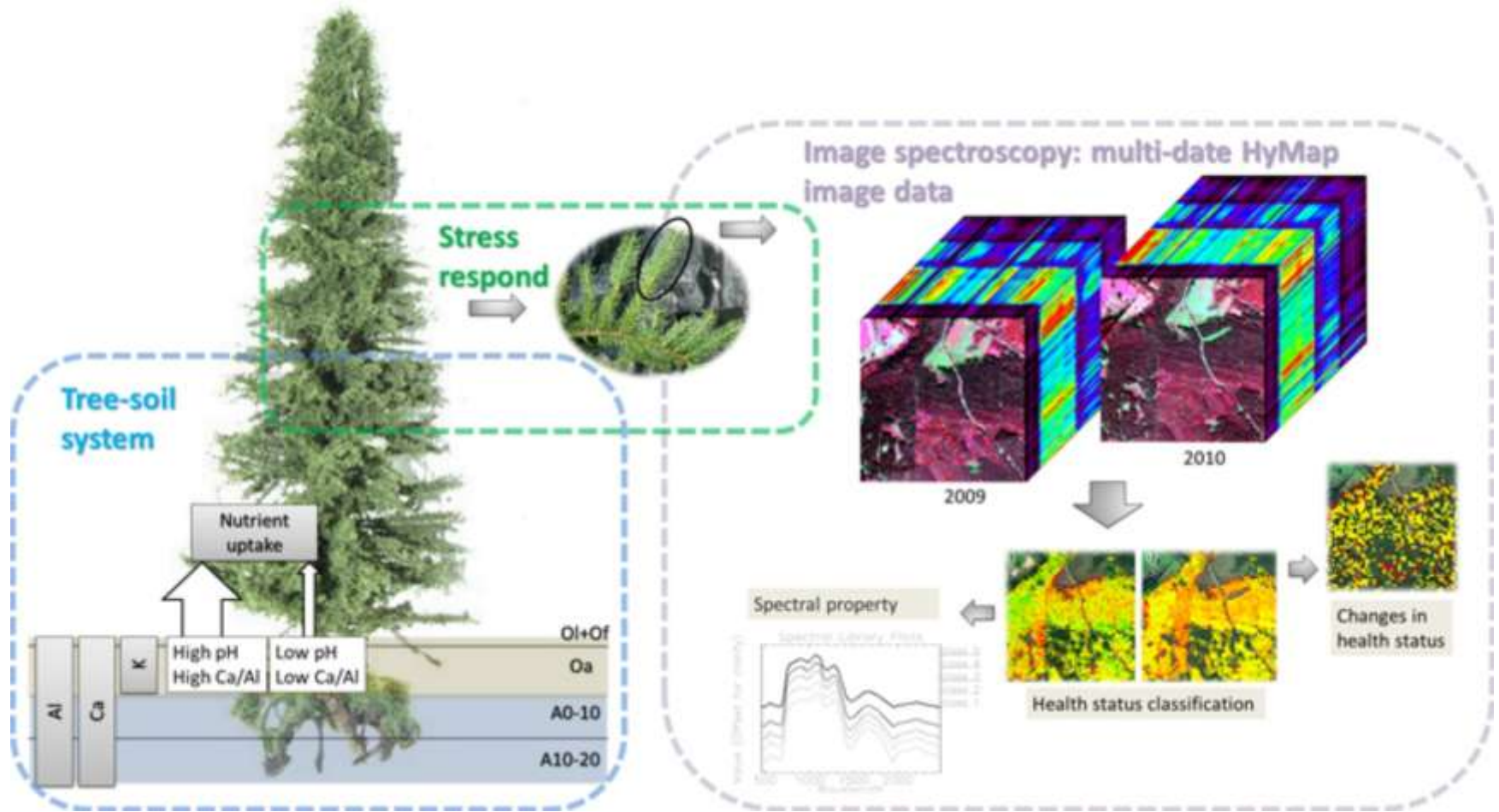# Black Triangle in CZ: forests in mountains, strip mines, reclamation sites

Central Europe – Czech Republic –

Krušné hory, Ore Mts.
Krkonoše / Giant Mts.

Central Europe
Czech Republic

Sokolov Region

Copyright: Pavel Bokr (2007)
www.geology.cz/foto/14650

Hyperspectral data for detection of subtle changes in tree health status

Hyperspectral projects of us:

1. **NASA project „Forest recovery in the Czech Republic" NAG5-5192 (CFDA #43.002), (1997-2000)**

   International collaboration: prof. Barrett N. Rock, Dr. Petya Entecheva-Campbell, Univ. New Hampshire, US

2. **INMON** – „Innovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data", funded by Ministry of Education, Youth and Sports, CZ **2012-2015**,

   Bilateral International US - Czech collaboration: Dr. Petya Campbell, Univ. Maryland/NASA GSFC

3. **HypSO** – „Assessment of Mining Related Impacts Based on Utilization of Airborne Hyperspectral Sensor", funded by the Czech Science Foundation, GA ČR 205/09/1989, **2009-2012**

4. **HyMountEcos** - Hyperspectral Remote Sensing for Mountain Ecosystems, funded by EUFAR (European Facility For Airborne Research), **2012**

   International collaboration: Dr. Bogdan Zagajewski (PI), Warsaw University, Department of Geoinformatics and Remote Sensing

1. Hypso: Hyperspectral Sokolov (2009-2013)

Assessment of Mining Related Impacts Based on Utilization of Airborne Hyperspectral Sensor

- ☐ **Primary Investigator:**

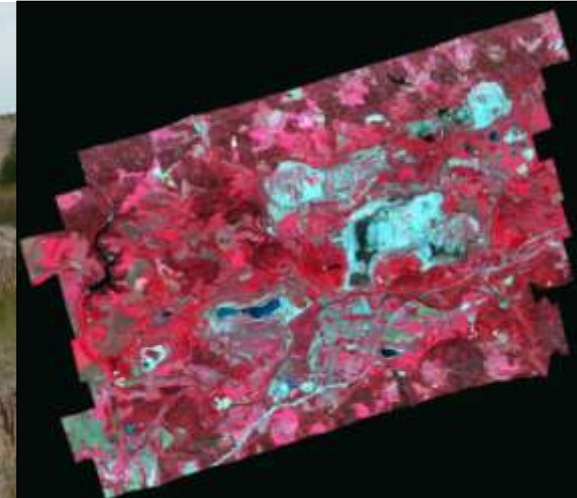- **Czech Geological Survey** – Veronika Kopačková (CGS)

- **Co-Investigator:**

- **Faculty of Science Charles University in Prague** – Dr. Jana Albrechtová, Dr. Zuzana Lhotáková, Dr. Lucie Kupková, Dr. Markéta Potůčková

- **CzechGlobe** – Ing. Jan Hanuš

Sokolov lignite basin

- ☐ **Test site:**

- Sokolov lignite basin

- Western part of the Czech republic

- Affected by long-term coal mining

Sokolov : HyMap data 2009 and 2010

- ☐ **HyMap airborne hyperspectral data**

- 125 bands
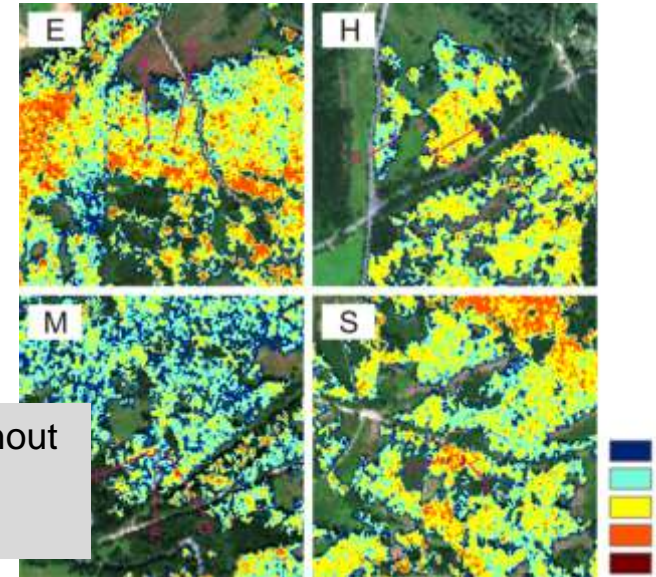- 450-2500 nm
- FWHM: 15 nm
- Spatial resolution 5m/pix

Sokolov : HyMap data 2009 and 2010

Norway spruce health assessment

☐ **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.

Kopackova V, Misurec J, Lhotakova Z, Oulehle F, Albrechtova J (2013). Using multi-date high spectral resolution data to assess the physiological status of macroscopically undamaged foliage on a regional scale. NTERNATIONAL JOURNAL OF APPLIED EARTH OBSERVATION AND GEOINFORMATION 27: 169-186. Part: B

Kopackova, V; Lhotakova, Z; Oulehle, F; Albrechtova, J (2015) Assessing forest health via linking the geochemical properties of a soil profile with the biochemical parameters of vegetation. INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY 12 (6): 1987-2002.

Lhotáková Z., Brodský L., Kupková L., Kopačková V., Potůčková M., Mišurec J., Klement A., Kovářová M., Albrechtová J. (2013): Detection of multiple stresses in Scots pine growing at post-mining sites using visible to near-infrared spectroscopy. ENVIRON. SCI.: PROCESSES IMPACTS,15: 2004-2015. DOI: 10.1039/C3EM00388D

2. NASA - Hyperspectral Krusne hory Mts. (1997- 2000)

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

        Petya Campbell

Co-I : Jana Albrechtová

ASAS'98 images and spectra of healthy (DC0) and damaged (DC 1-4) canopies (Entcheva et al. 2004)

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

Detection of previsible damage stages (DC0 a DC1):
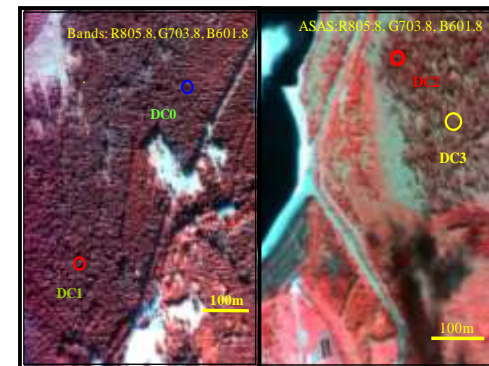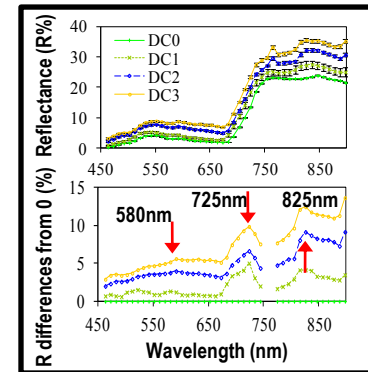
Optical indices: C1, RE1 and RARSc

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*

•*Campbell, PKE, Rock, BN, Martin, ME, Neefus, CD, Irons, JR, Middleton, EM, Albrechtová, J. Detection of initial damage in Norway spruce canopies using hyperspectral airborne data. In: International Journal of Remote Sensing, 2004, 25, 24, s. 5557-5583*

Albrechtová, J.; Seidl, Z.; Aitkenhead-Peterson, J.; Lhotáková, Z.; Rock, B.N.; Alexander, J.E.; Malenovský, Z.; McDowell, W.H. (2008): Spectral analysis of coniferous foliage and possible links to soil chemistry: Are spectral chlorophyll indices related to forest floor dissolved organic C and N? SCIENCE OF THE TOTAL ENVIRONMENT, 404: 424-432, ISSN 0048-9697

3. INMON: Hyperspectral Krusne hory Mts. (2012-2015)

Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data

The main goal: assessment of the temporal changes in the physiological status of Norway spruce forests in the Krušné Hory Mts. using two hyperspectral data sets acquired in 1998 and 2013.

□ 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
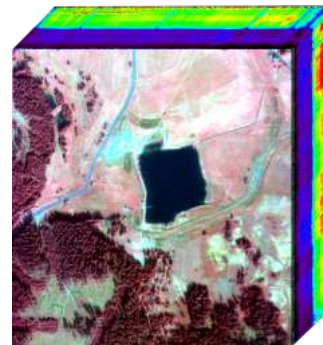
- ▪ **Czech Geological Survey**
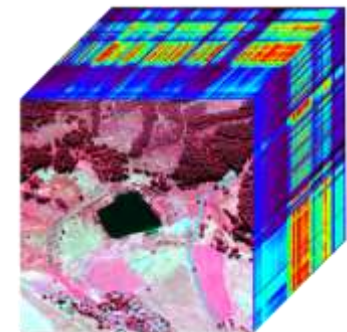
  Mgr. Veronika Kopačková, Mgr. Jan Mišurec

- ▪ **University of Maryland BC, NASA GSFC**
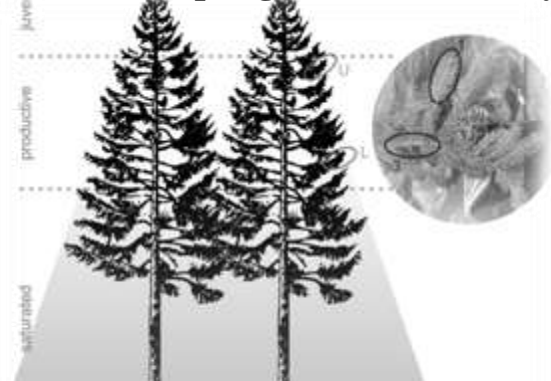
  Dr. Petya Entcheva-Campbell

ASAS 1998:

APEX 2013:

Inovation of methods for monitoring of health status of Norway spruce stands in the Krusne hory Mts. with the use of hyperspectral data
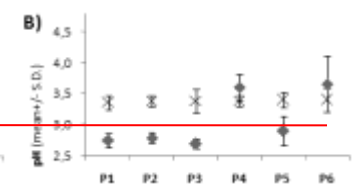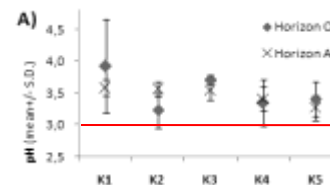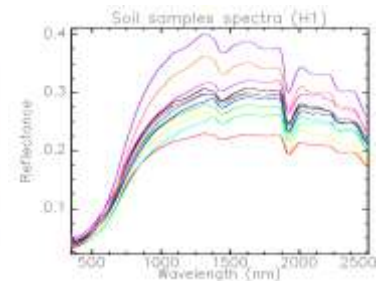
The main goal: assessment of the temporal changes in the physiological status of Norway spruce forests in the Krušné Hory Mts. using two hyperspectral data sets acquired in 1998 and 2013.

Groundtruth:

**Needle sampling: Foliar chemistry – laboratory spectroscopy**

LAI measurements

Soil analyses:

ABSTRACT: The Ore Mountains are an example of the region that suffered from severe environmental pollution caused by long-term coal mining and heavy industry leading to massive dieback of the local Norway spruce forests between the 1970's and 1990's. The situation became getting better at the end of 1990's after pollution loads significantly decreased. In 1998 and 2013, airborne hyperspectral data (with sensor ASAS and APEX, respectively) were used to study recovery of the originally damaged forest stands and compared them with those that have been less affected by environmental pollution. The field campaign (needle biochemical analysis, tree defoliation etc.) accompanied hyperspectral imagery acquisition. An analysis was conducted assessing a set of 16 vegetation indices providing complex information on foliage, biochemistry and canopy biophysics and structure. Five of them (NDVI, $NDVI_{705}$, VOG_1, MSR and TCARI/OSAVI) showing the best results were employed to study spatial gradients as well as temporal changes. The detected gradients are in accordance with ground truth data on representative trees. The obtained results indicate that the original significant differences between the damaged and undamaged stands have been generally levelled until 2013, although it is still possible to detect signs of the previous damages in several cases.
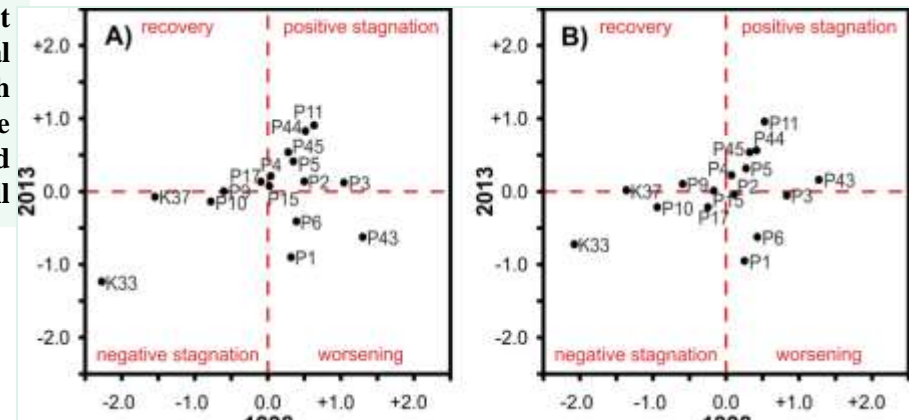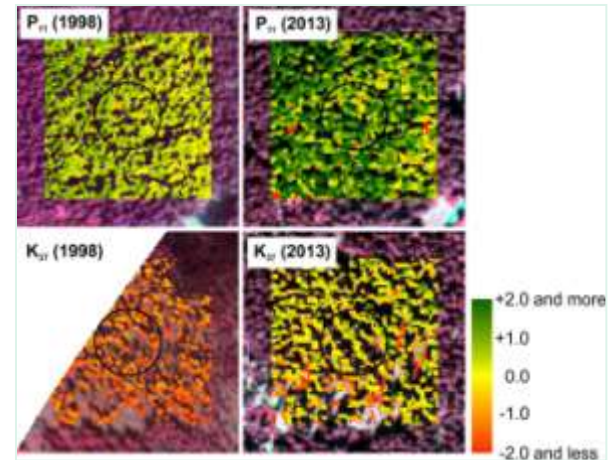
Article

Detection of Spatio-Temporal Changes of Norway Spruce Forest Stands in Ore Mountains Using Landsat Time Series and Airborne Hyperspectral Imagery

Jan Mišurec [1,2,*], Veronika Kopačková [1], Zuzana Lhotáková [3], Petya Campbell [4] and Jana Albrechtová [3]

[1] Czech Geological Survey, Klárov 3, Prague 118 21, Czech Republic; veronika.kopackova@geology.cz
[2] Faculty of Science, Department of Applied Geoinformatics and Cartography, Charles University in Prague, Albertov 6, Prague 128 43, Czech Republic
[3] Faculty of Science, Department of Experimental Plant Biology, Charles University in Prague, Viničná 5, Prague 128 44, Czech Republic; zuza.lhotak@seznam.cz (Z.L.); jana.albrechtova@natur.cuni.cz (J.A.)
[4] Joint Center for Earth Systems Technology, University of Maryland Baltimore County and Biospheric Sciences, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA; petya.k.campbell@nasa.gov
[*] Correspondence: jmas@volny.cz; Tel.: +420-257-089-511

Abstract: The study focuses on spatio-temporal changes in the physiological status of the Norway spruce forests located at the central and western parts of the Ore Mountains (northwestern part of the Czech Republic), which suffered from severe environmental pollution from the 1970s to the 1990s. The situation started improving after the pollution loads decreased significantly at the end of the 1990s. The general trends in forest recovery were studied using the tasseled cap transformation and disturbance index (DI) extracted from the 1985–2015 time series of Landsat data. In addition, 16 vegetation indices (VIs) extracted from airborne hyperspectral (HS) data acquired in 1998 using the Advanced Solid-State Array Spectroradiometer (ASAS) and in 2013 using the Airborne Prism Experiment (APEX) were used to study changes in forest health. The forest health status analysis of HS image data was performed at two levels of spatial resolution: at a tree level (original 2.0 m spatial resolution), as well as at a forest stand level (generalized to 6.0 m spatial resolution). The temporal changes were studied primarily using the VOGa vegetation index (VI) as it was showing high and stable sensitivity to forest damage for both spatial resolutions considered. In 1998, significant differences between the moderately to heavily damaged (central Ore Mountains) and initially damaged (western Ore Mountains) stands were detected for all the VIs tested. In 2013, the stands in the central Ore Mountains exhibited VI values much closer to the global mean, indicating an improvement in their health status. This result fully confirms the finding of the Landsat time series analysis. The greatest difference in Disturbance Index (DI) values between the central (1998: 0.37) and western Ore Mountains stands (1998: −1.21) could be seen at the end of the 1990s. Nonetheless, levelling of the physiological status of Norway spruce was observed for the central and western parts of the Ore Mountains in 2013 (mean DI values −1.04 (western) and −0.66 (central)). Although the differences between originally moderately-to-heavily damaged, and initially damaged stands generally levelled out by 2013, it is still possible to detect signs of the previous damage in some cases.

Mišurec J, Kopačková V, Lhotáková Z, Campbell P, Albrechtová J. (2016): Detection of spatio-temporal changes of Norway spruce forest stands in Ore Mountains using Landsat time series and airborne hyperspectral imagery. Remote Sensing, 8, 92; doi:10.3390/rs8020092.

4. HyMountEcos - Hyperspectral Remote Sensing for Mountain Ecosystems 2012

- Giant Mountains,

- aims to prepare processing chain for mountain ecosystem analysis and monitoring using aerial hyperspectral data

- Project team: Warsaw University, Faculty of Science Charles University in Prague (lead by L. Kupkova)

- Duration: 2012

- Data: APEX, 2 m resolution

- Project goals

  - Mountain ecosystems mapping and inventarization.

  - Analyses of ecosystems species composition and invasive species introduction.

  - Analyses and evaluation of forest ecosystems conditions/health (biophysical parameters like chlorophyll content, LAI, water content).

  - Proposal of the processing chain for mountain ecosystems monitoring using hyperspectral technologies and potential/feasibility assessment of hyperspectral data/technologies for the mountain ecosystems analysis and monitoring.

4. HyMountEcos - Hyperspectral Remote Sensing for Mountain Ecosystems 2012

Renáta Suchá; Lucie Kupková; Lucie Červená; Lucie Jakešová; Stanislav Březina; Bogdan Zagajewski, Jana Albrechtová: **The Classification Of Vegetation Above The Tree Line In Krkonoše Mts. National Park Using Remote Sensing Hyperspectral Data.** **EuJRS - submitted**

Closed alpine grasslands
- *Nardus stricta* stands
- Species-rich vegetation with high cover of forbs

Subalpine tall grasslands
- *Calamagrostis villosa* stands
- *Molinia caeruela* stands
- *Deschampsia cespitosa* stands

- *Pinus mugo* scrub
- Subalpine *Vaccinium* vegetation
- Alpine heathlands
- Wetlands and peat bogs
- Water areas
- Block fields and anthropogenic areas

- aerial hyperspectral data (AISA Dual and APEX sensors) and Sentinel-2A data.
- Comparison of classification outputs (accuracy, maps) of pixel-based (Suport Vector Machine, Neural Net, Maximum Likelihood) and object-based approach.
- Comparison of hyperspectral classification with results on multispectral data classifications (orthoimages, WoldView-2and Landsat 8 images) for tundra in the Krkonoše Mts
- The best classification results (overall accuracy 84.3%, Kappa coefficient = 0.81) were achieved for 1m AISA Dual data using per-pixel SVM classifier for 40 PCA bands.

Conclusions

1. **North Western Czech Republic: unique area affected by extreme environmental pollution and socio-economic changes**
    temporal changes in the decline/recovery in forest extent, function and health, and the conversion from spruce forest cover to other forests or other cover types connected with socio-economic driving forces

2. **Ideal test site for forest health evaluation, testing the methods**

3. **Ideal test site for forest health evaluation, in context with socio-economic changes**

Projects and collaboration welcome

Proposition of hyperspectral review paper:

Review paper : proposed by Jana Albrechtová, Petya Campbell, Lucie Kupková

Review of the available airborne hyperspectral datasetes acquired in the SCERIN region and their use for vegetation monitoring

1. **List of available datasets (dataset details, sensor, resolution, localization, timing, owner – contact person)**

2. **Comparison of different datasets and sensors**

3. **Use of datasets for vegetation monitoring**
   - **Forest ecosystems:**
     - **Monitoring tree physiological status**
     - Mountain ecosystems mapping and inventarization.
     - Analyses of ecosystems species composition and invasive species introduction.
   - **Agriculturral ecosystems**

4. potential/feasibility assessment of hyperspectral data/technologies for the different ecosystem analysis and monitoring.