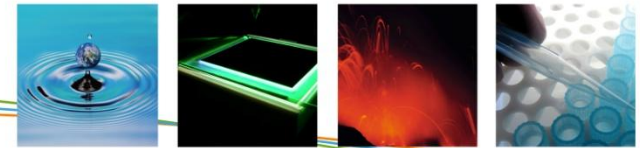

Environmental monitoring of mining in hyperspace

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Outline

- **Hypertemporal**
  - Orenburg-Karabash
- **Hyperspectral**
  - Mostar
  - Rosia Montana
- **Hyperspatial**
  - Mostar

Hypertemporal: Time series analysis of SPOT-VEGETATION (Orenburg-Karabash)

» Tote, C., M. Goossens, B. Williamson, W. Purvis, D. Bellis, V. Udachin, E. Swinnen, and I. Reusen. 2012. "Vegetation stress due to mining impact in Karabash using TSA of SPOT-VGT." 1st EARSeL Workshop on Temporal Analysis of Satellite Images.

» Tote, C., S. Delalieux, M. Goossens, B. Williamson, and E. Swinnen. submitted. "Monitoring environmental health using SPOT-Vegetation derived indices in Karabash, Russia." *International Journal of Remote Sensing.*

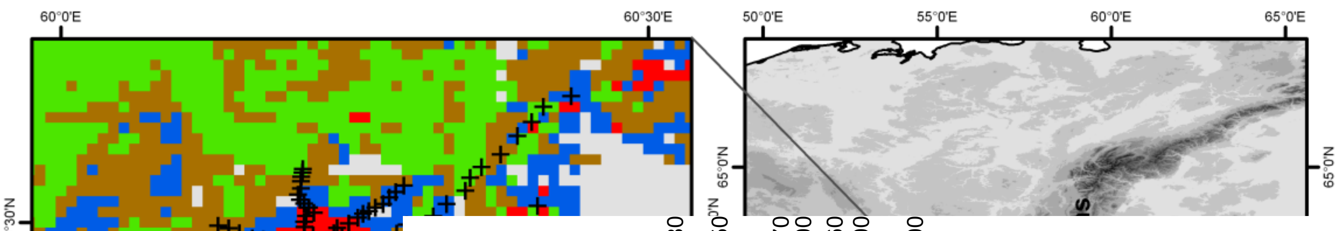
» Study area: Karabash → large scale environmental impact from gaseous and particulate emissions from copper smelter

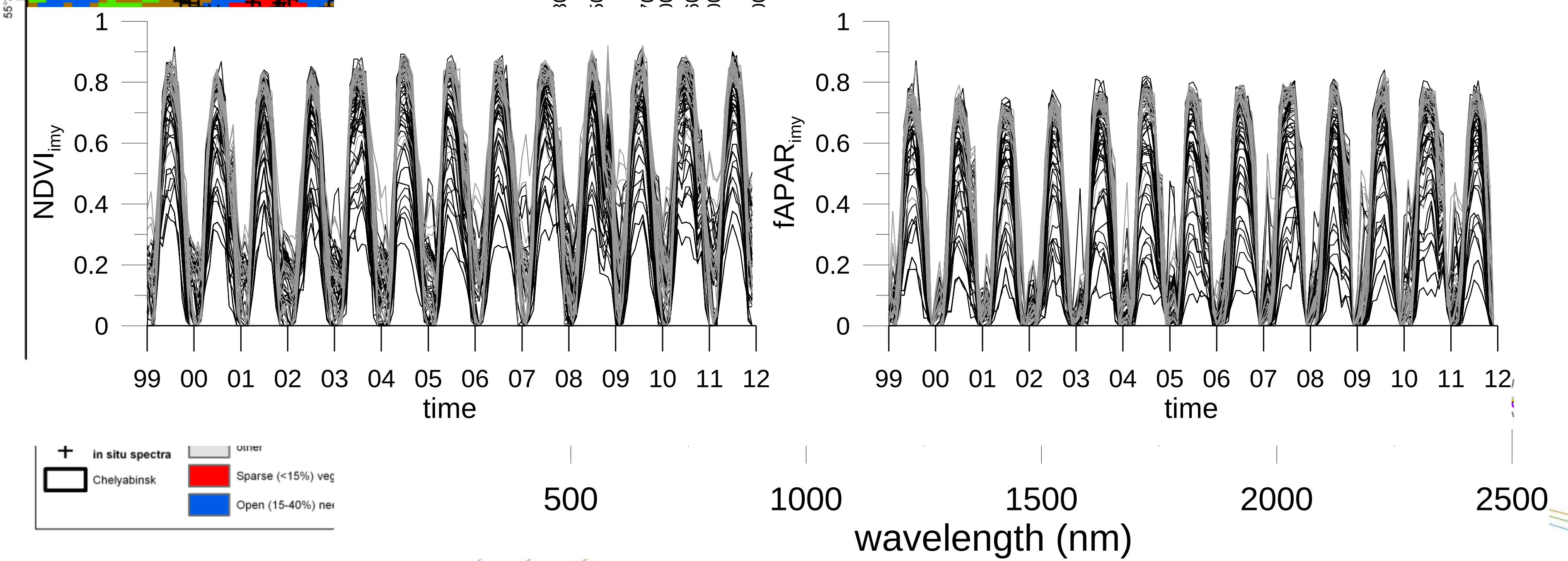
Data

- » Reference: GlobCover (Arino et al.2007)
- » *In situ* data: 140 Birch spectra (GEOSENSE)

Dec/2011

(fAPAR)





Methods

- Spectral indices from *in situ* spectra
- Time series indice
  - Mean values $\mu[N$
  - Coefficients of v
  - Z-scores Z_{NDVI} and
  - Trend analysis c
- Correlation analys
  - With distance fr
  - Between spectr

Name	Abbrev.	Formula[a]	References
Normalized green red difference index	*NGRDI*	$(R_g - R_r)/(R_g + R_r)$	Tucker (1979)
Triangular greenness index	*TGI*	$-0.5 \cdot [(\lambda_r - \lambda_b) \cdot (R_r - R_g) - (\lambda_r - \lambda_g) \cdot (R_r - R_b)]$	Hunt et al. (2011)
Modified chlorophyll absorption reflectance index	*MCARI*	$[(R_{700} - R_r) - 0.2 \cdot (R_{700} - R_g)] \cdot (R_{700}/ R_r)$	Daughtry et al. (2000)
Transformed chlorophyll absorption reflectance index	*TCARI*	$3 \cdot [(R_{700} - R_r) - 0.2 \cdot (R_{700} - R_g) \cdot (R_{700}/ R_r)]$	Haboudane et al. (2002)
Triangular chlorophyll index	*TCI*	$1.2 \cdot (R_{700} - R_g) - 1.5 \cdot (R_r - R_{550}) \cdot \sqrt{(R_{700}/ R_r)}$	Haboudane et al. (2008)
Soil adjusted vegetation index	*SAVI*	$(1 + 0.5) \cdot (R_n - R_r)/(R_n + R_r + 0.5)$	Huete (1988)
Optimized soil adjusted vegetation index	*OSAVI*	$(1 + 0.16) \cdot (R_n - R_r)/(R_n + R_r + 0.16)$	Rondeaux et al. (1996)
Modified soil adjusted vegetation index	*MSAVI*	$0.5 \cdot \{2 \cdot R_n + 1 - \sqrt{[(2 \cdot R_n + 1)^2 - 8 \cdot (R_n - R_r)]}\}$	Qi et al. (1994)
Normalized difference vegetation index	*NDVI*	$(R_n - R_r)/(R_n + R_r)$	Tucker (1979)
Triangular vegetation index	*TVI*	$0.5 \cdot [120 \cdot (R_n - R_g) - 200 \cdot (R_r - R_g)]$	Broge and Leblanc (2000)
Ratio vegetation index R_{760}/R_{900}	*$RVI_{760-900}$*	R_{760}/R_{900}	-

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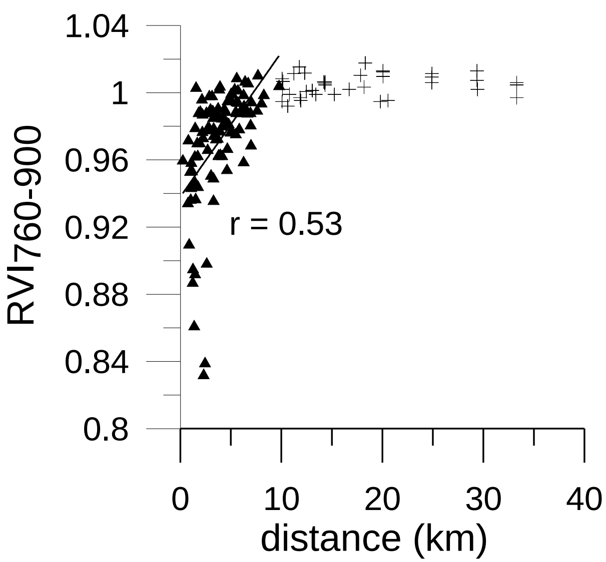
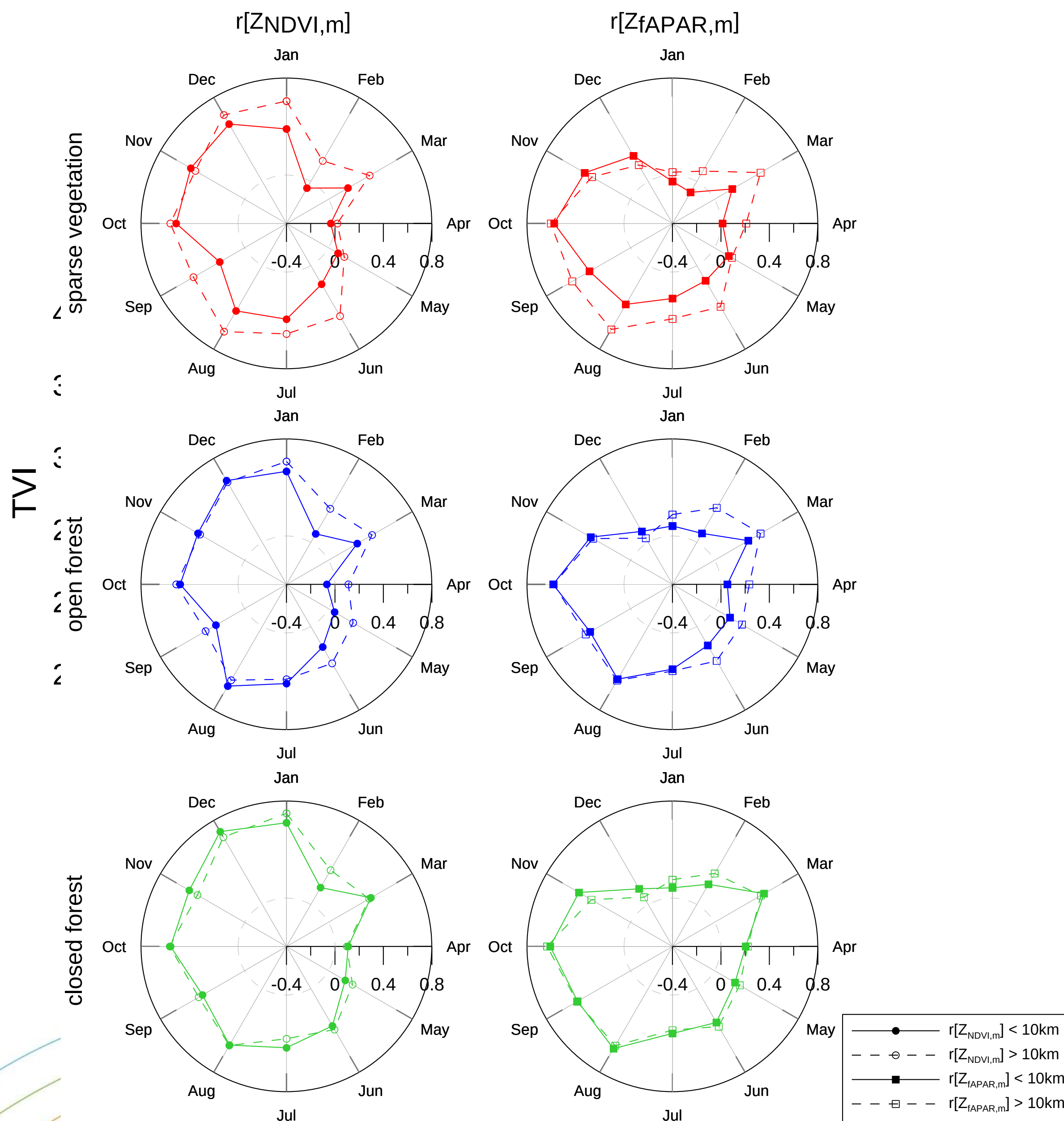
Results

» Relation with distance

» spectral indices





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Results

- Both spectral indices, related to leaf pigments, internal leaf structure and thus plant health, derived from *in situ* birch reflectance spectra, and indices derived from SPOT-VEGETATION NDVI and fAPAR time series, have shown that the most affected area ranges up to 10 km distance from the smelter.

- Correlation analyses between the spectral and time series indices have revealed that vegetation stress impedes a gradual increase of photosynthetic activity in close proximity of the smelter, which is observed at larger distances.

Hyperspectral: Water quality (Mostar)

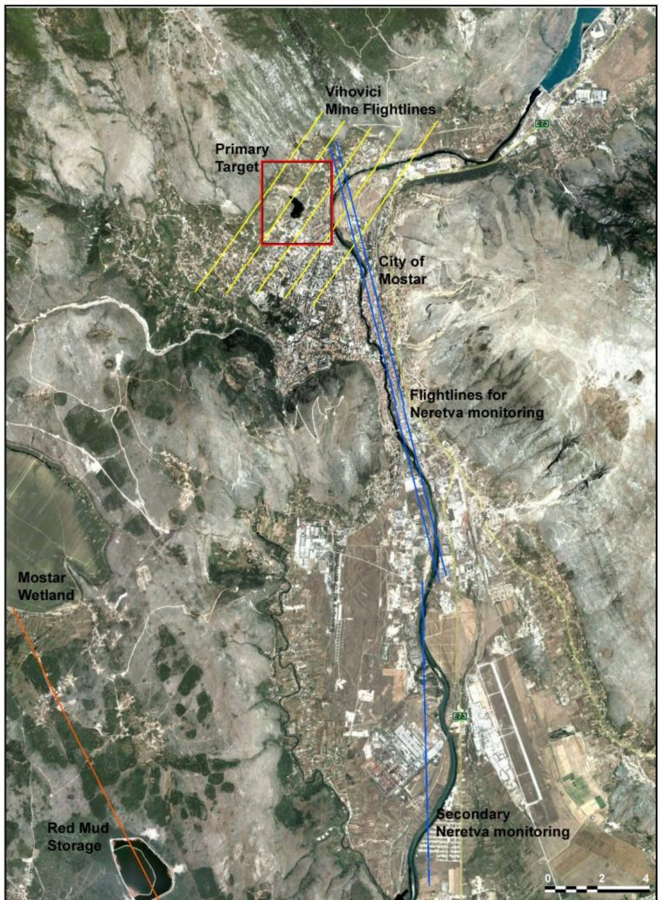
Vihovici Lake

Neretva River

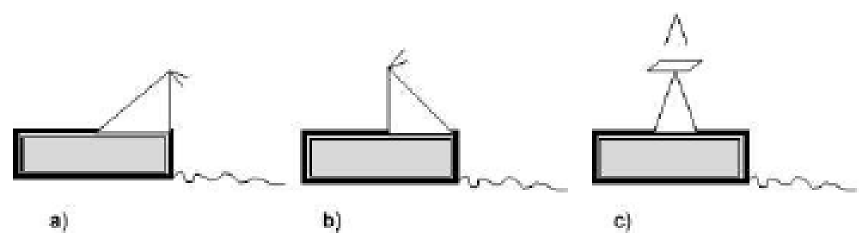
Hyperspectral: Water quality

- Preparation

Flight campaign planning

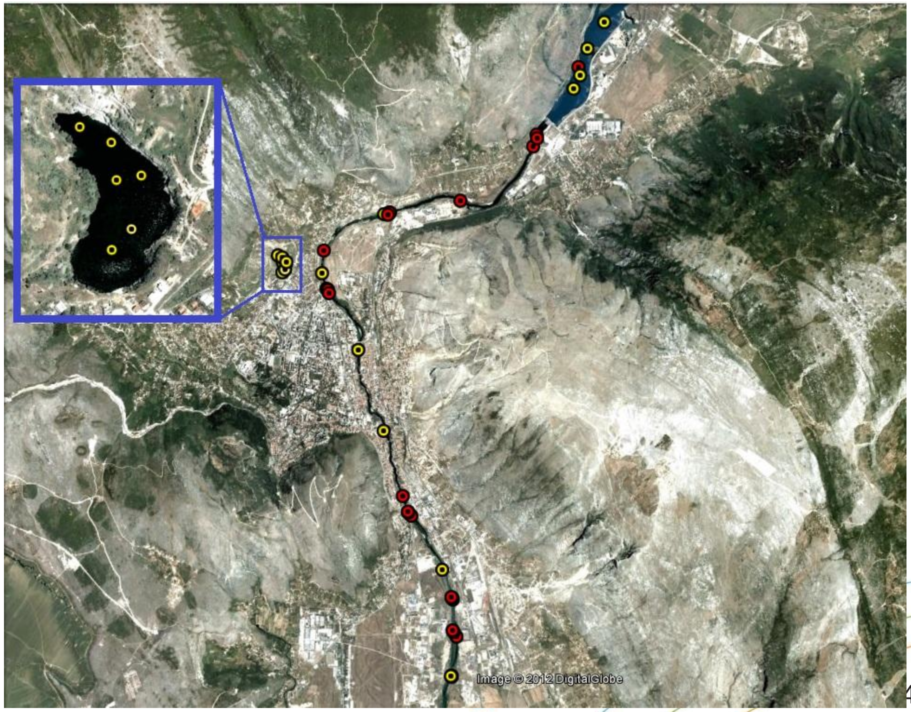


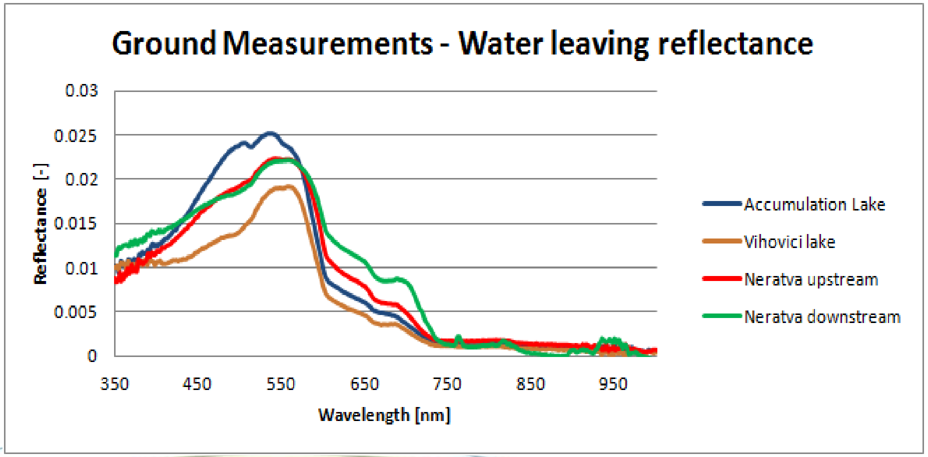
Training on use of ASD field spectrometer for water leaving reflectance



Hyperspectral: Water quality

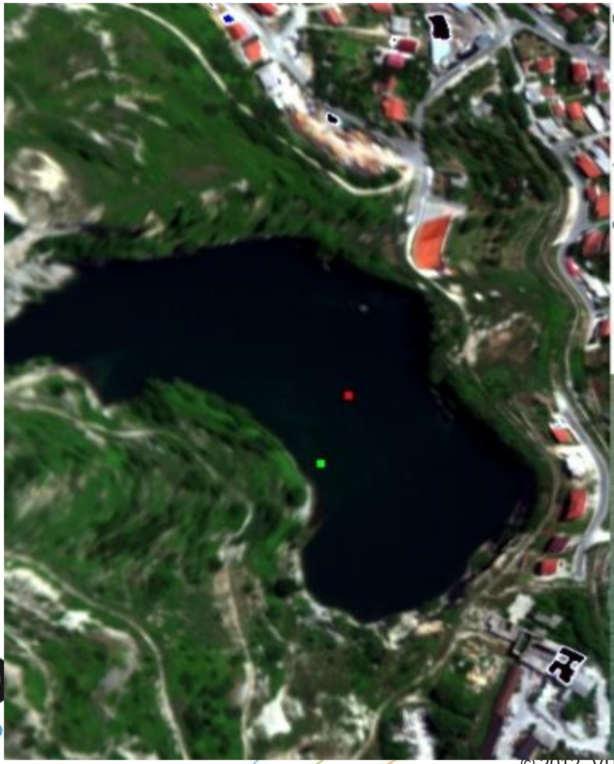
- Data: field data (Mostar university, Photon, GEOSENSE)
  - Water samples for water quality analysis
  - Water leaving reflectance
  - Spectral reflectance targets
  - GPS measurements

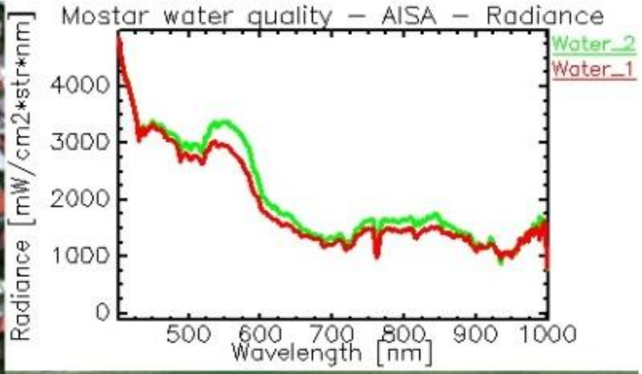




Hyperspectral: Water quality

- Data: hyperspectral airborne data
  - Acquired on 19/05/2001 with AISA-EAGLE sensor
  - 8 flightlines
  - Example:





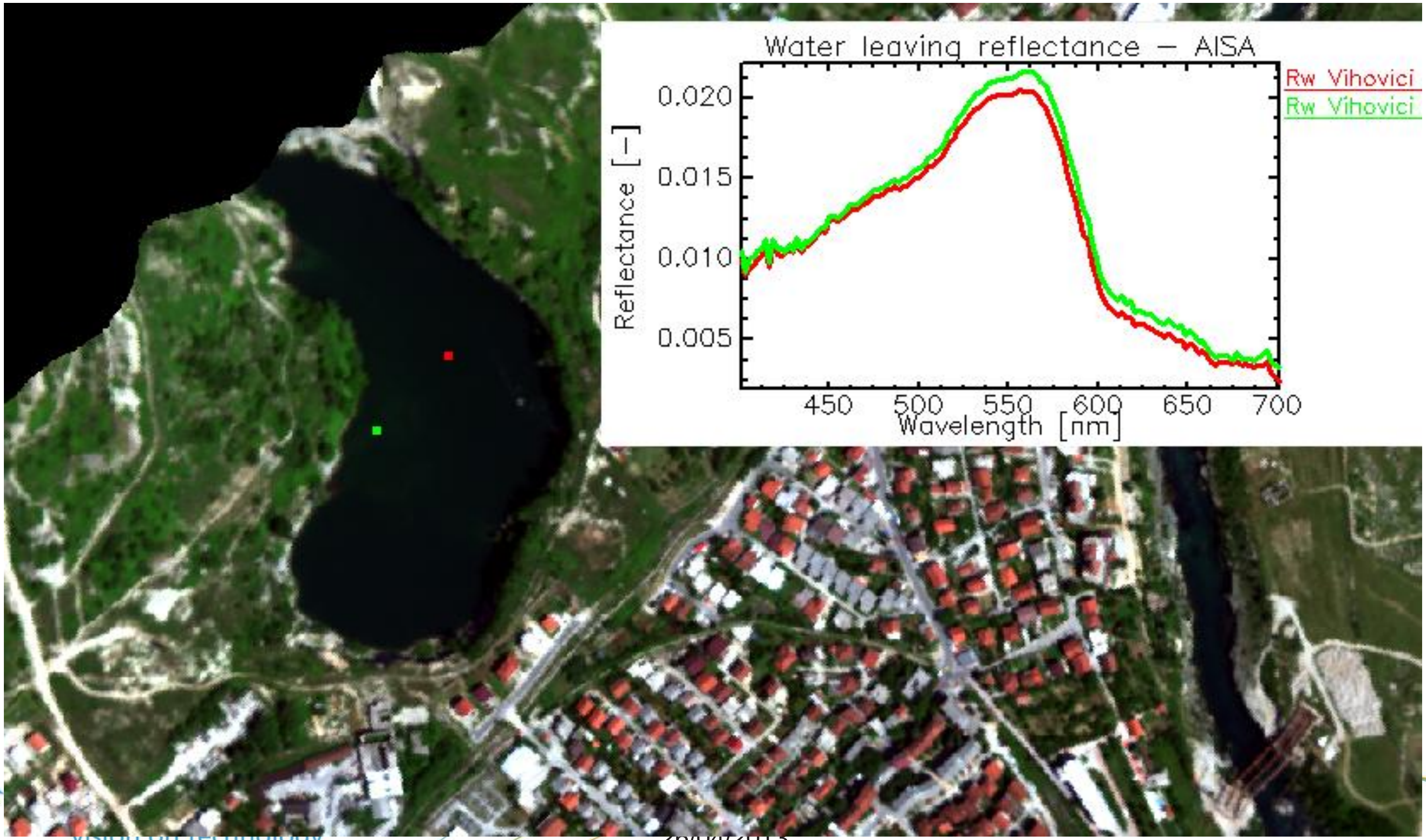
Hyperspectral: Water quality

- Methodology
  - Airborne image preprocessing (ATCOR + vicarious calibration) (PHOTON)
  - In-situ water spectra analysis (in-situ data vs lab data) (Mostar university)
  - Airborne vs in-situ spectral analysis (AISA EAGLE vs ASD)
  - Airborne water quality analysis (AISA EAGLE vs lab)

Hyperspectral: Water quality

» Results

  » Airborne image preprocessing with ATCOR and vicarious calibration



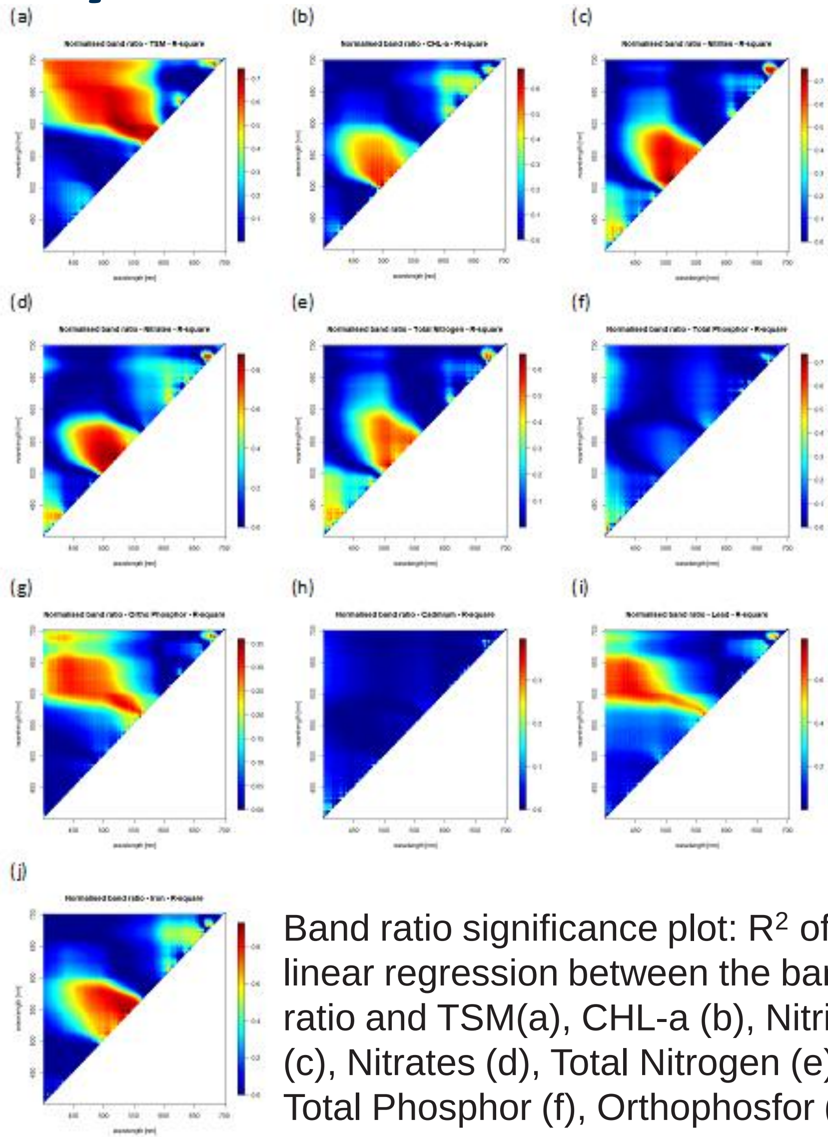
Hyperspectral: Water quality

- » Results
  - » In-situ water spectra analysis

Relationship between the Rw spectra and the different water quality parameters:
Band ratio analysis

$$WQP_i = I_i + S_i * \frac{b1_i - b2_i}{b1_i + b2_i}$$

TSM: 550 and 600nm
CHL-a: 480-575nm and 675nm
=> correlated with Nitrates and TotalN
Lead and Iron: 425nm and 550nm
Phosphor and Cadmium: poor correlations



Band ratio significance plot: R^2 of the linear regression between the band ratio and TSM(a), CHL-a (b), Nitrites (c), Nitrates (d), Total Nitrogen (e), Total Phosphor (f), Orthophosfor (g), Cadmium (h), Lead (i) and Iron(j).

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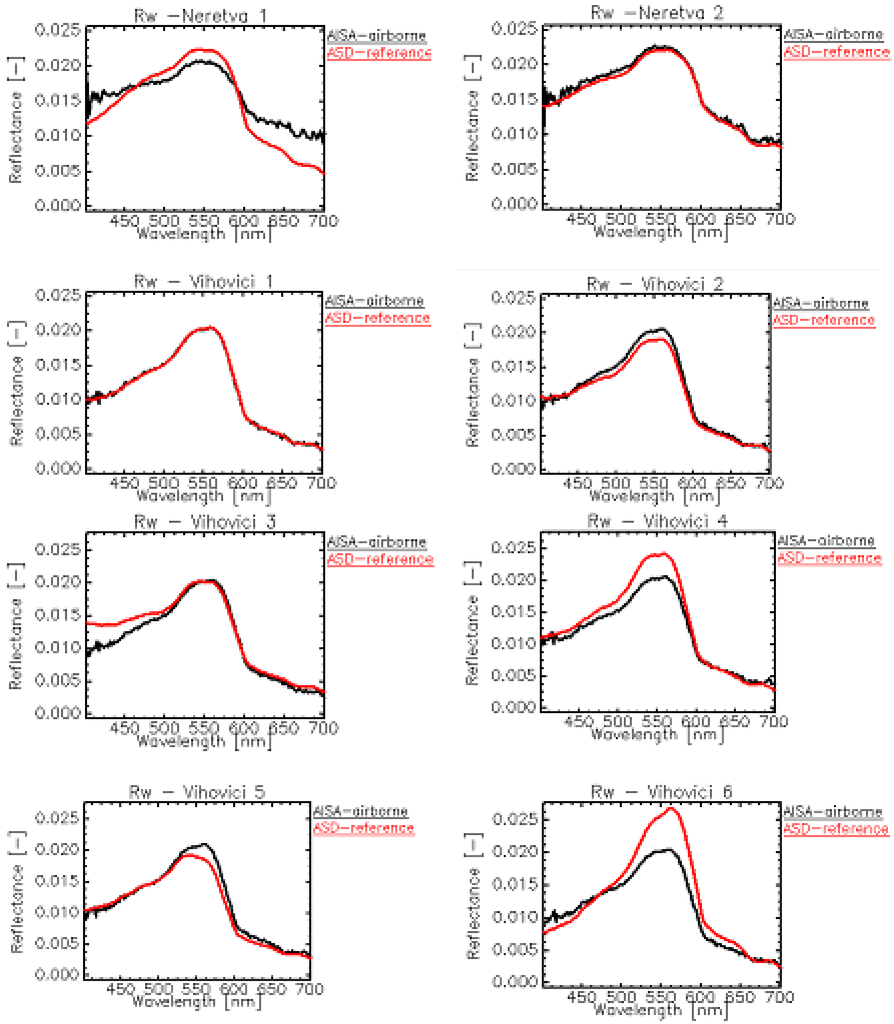
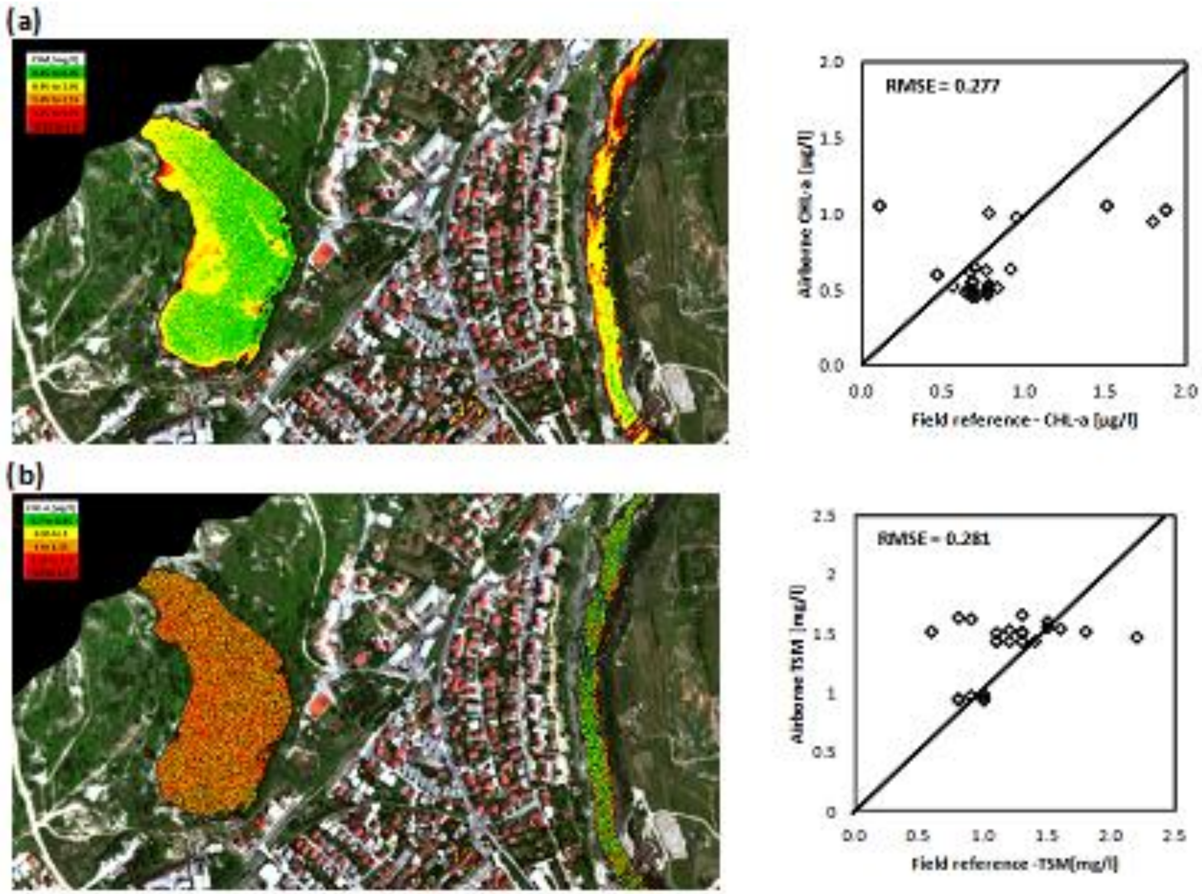
Hyperspectral: Water quality

» Results: Airborne vs in-situ spectral analysis (AISA EAGLE vs ASD)



Hyperspectral: Water quality

» Results: Airborne water quality analysis (AISA EAGLE vs lab)



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Hyperspectral: Water quality

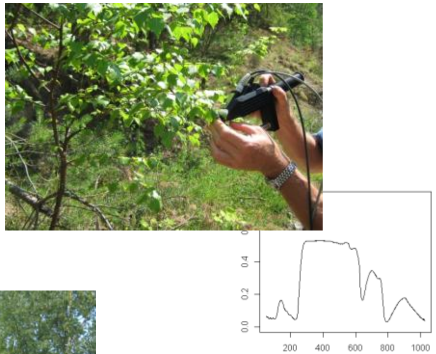
- Results
  - The Rw spectra measured during the Mostar field campaign are related to the concentration values
  - Notable influence of the TSM concentration in the spectra
  - No notable influence of CHL concentration in spectra
  - The measurements taken at the Neretva river were effected by the bottom reflectance

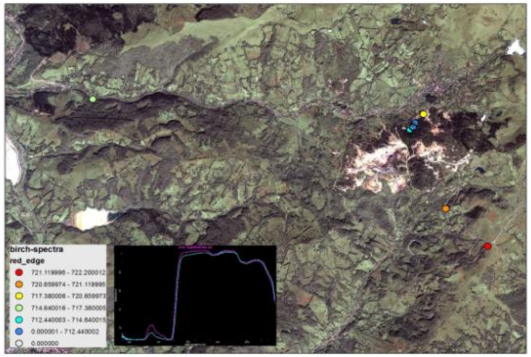
Hyperspectral: Vegetation stress (Rosia Montana)

» Study area : Rosia Montana

Data

- In-situ data
  - Leaf spectral samples (full spectral range 350-2500 nm) (UBB, GEOSENSE, VITO)
  - Destructive leaf analyses (pigments, heavy metals) (UBB)
- Airborne AISA Eagle dataset
  - 64 bands ranging from 408-996 nm (VIS-NIR)
- WorldView 2 images 2011 and 2012
  - 8 spectral bands (VIS-NIR)



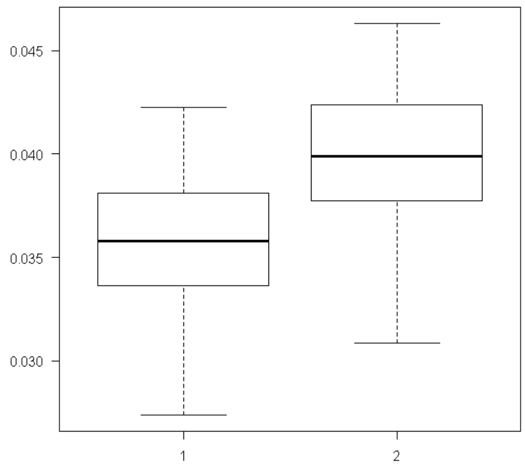


Methodology

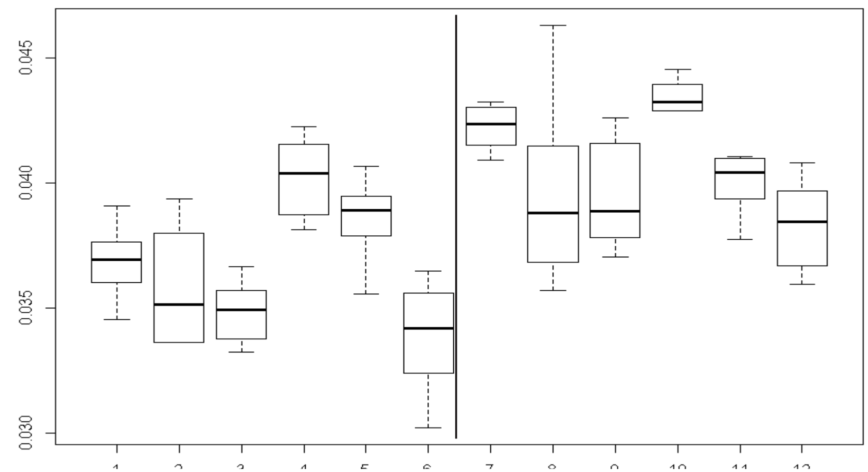
- Leaf spectral analysis (with focus on birches) via
  - Decision tree classification
    - Polluted vs non-polluted tree
  - Vegetation indices
- Airborne flight strip analysis (with focus on birches) via
  - Extend the outcome of the leaf spectral analysis to the airborne analysis for an airborne estimation of polluted birch trees
  - Vegetation indices
    - Polluted vs. remote areas
- WV 2 analysis via
  - Vegetation indices
    - Trees vs shrubs and grassland
    - Differentiation of different tree species
    - Polluted vs non-polluted trees

Results

- » Normalized Difference Lignin Index performs well in estimating the degree of pollution in birch leaves
  - » NDLI = [log (1/R1754)-log (1/R1680)]/[log (1/R1754) + log (1/R1680)]) Serrano et al., 2002
  - » Higher NDLI values indicate the presence of more lignin which is considered as a plant response to various environmental or stress factors



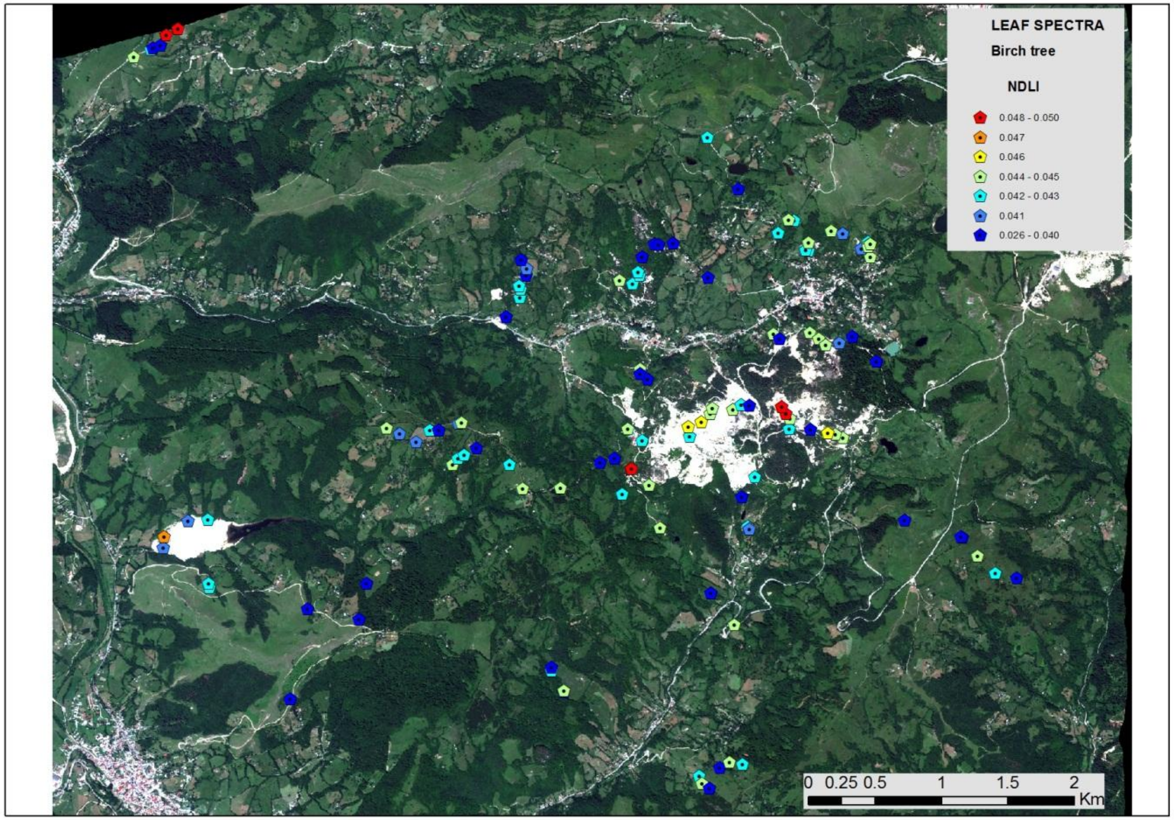
non- polluted polluted



non- polluted polluted

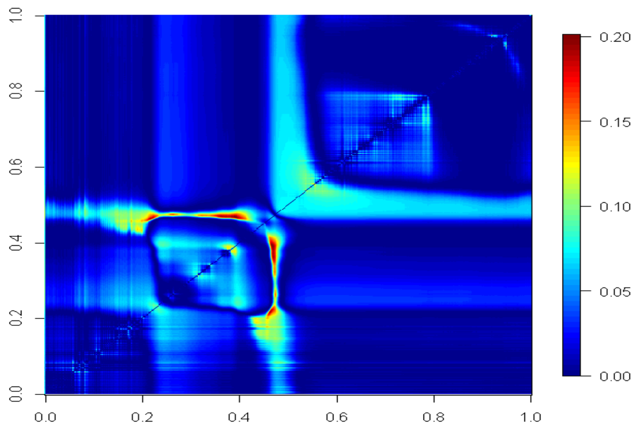
Results

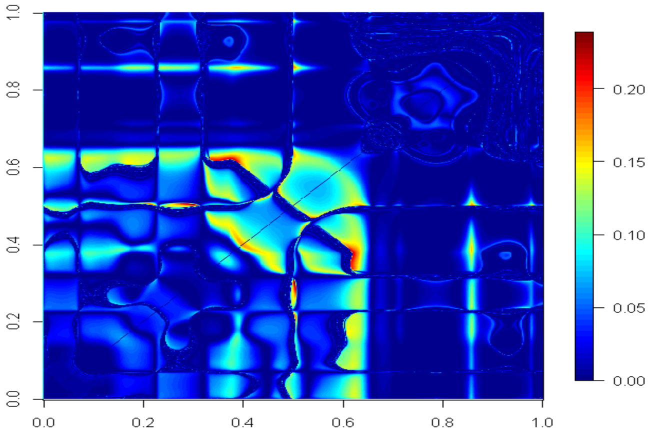
» Overall higher NDLI values can be observed for birch trees located near to or on the tailing dams



Results

- From a linear regression analysis, it was found that wavelength 647nm was slightly correlated with NDLI⟹ chlorophyll b!
- R^2 values of regression analyses of standardized ratio indices containing VIS-NIR wavelengths vs. NDLI





If only VNIR bands are available, chlorophyll related indices should perform the best to detect mining impact on vegetation

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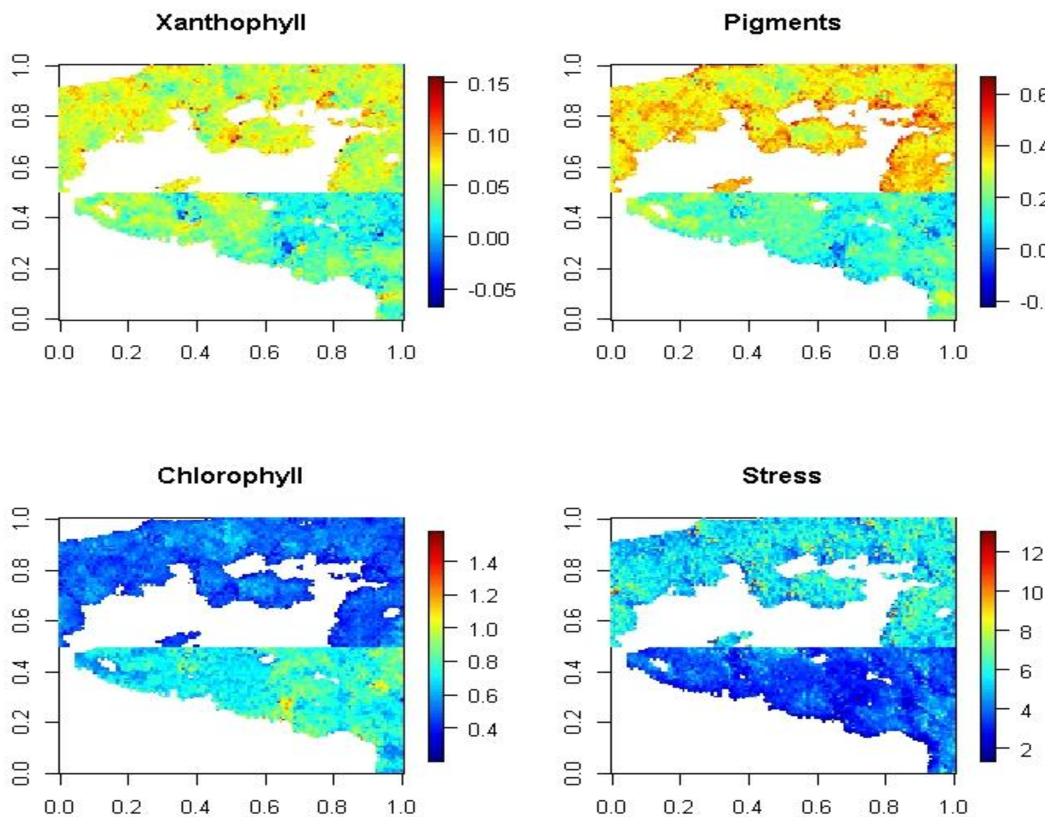
Results

- Chlorophyll indices to detect polluted trees in airborne dataset
  - Photochemical Reflectance Index – PRI
  - Normalized Pigment Chlorophyll Ratio Index – NPCI
  - Simple Ratio Pigment Index – SRPI
  - Stress-Related index – SR (695/420)

non-polluted area

polluted area



Results

- Chlorophyll indices to detect polluted trees in airborne dataset:
  - Unexpected results of the
    - Photochemical Reflectance Index – PRI
    - Normalized Pigment Chlorophyll Ratio Index – NPCI
    - Stress-Related index – SR (695/420)
  - Check with a subset of the leaf reflectance dataset revealed:
    - Leaf reflectances in July confirmed findings from literature
    - Leaf reflectances of August showed opposite effects
  - Something to do with autumn leaf colouring which occurred earlier in polluted areas?
      - Incentive for further research!

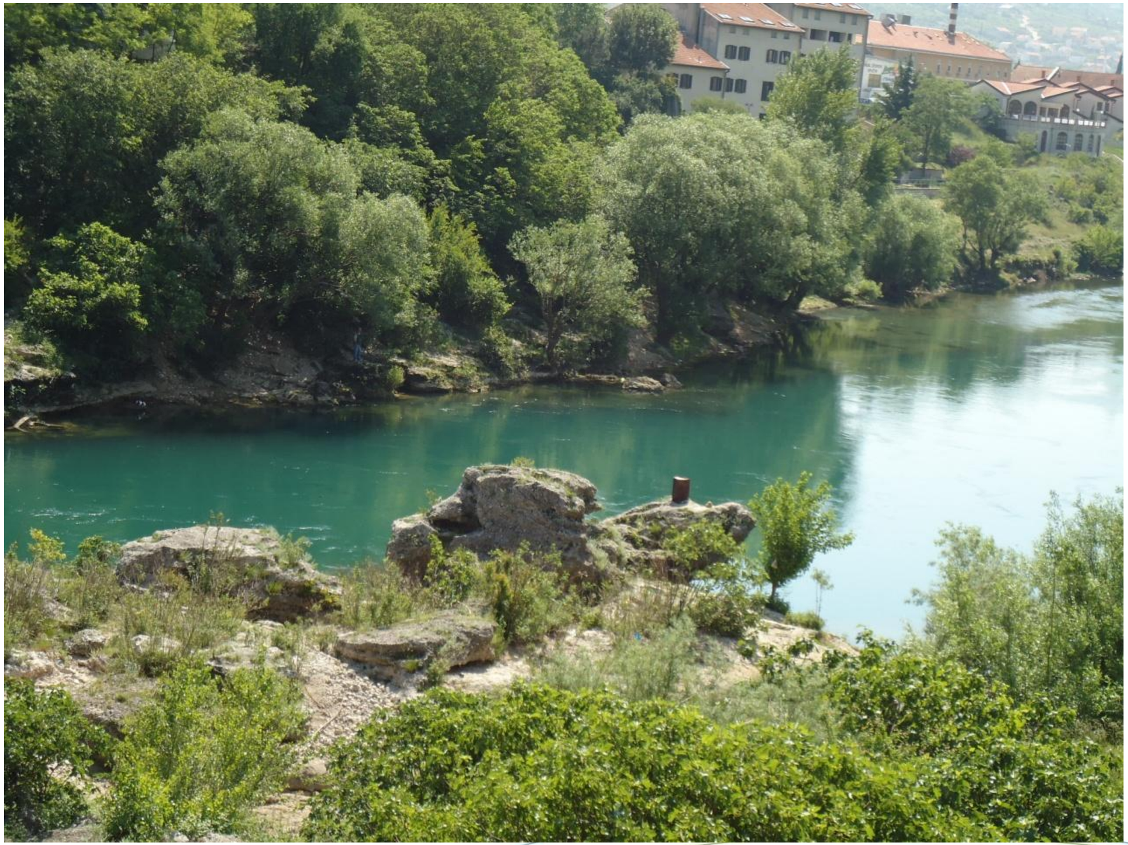
Results

- If SWIR bands are available: Normalized Difference Lignin Index (NDLI) performs well in estimating the degree of pollution in birch leaves

- If only VNIR bands are available, chlorophyll related indices should perform the best to detect mining impact on vegetation

Hyperspatial: fusion WorldView-2 and Smartplanes UAS (Mostar)

- Study area: Mostar

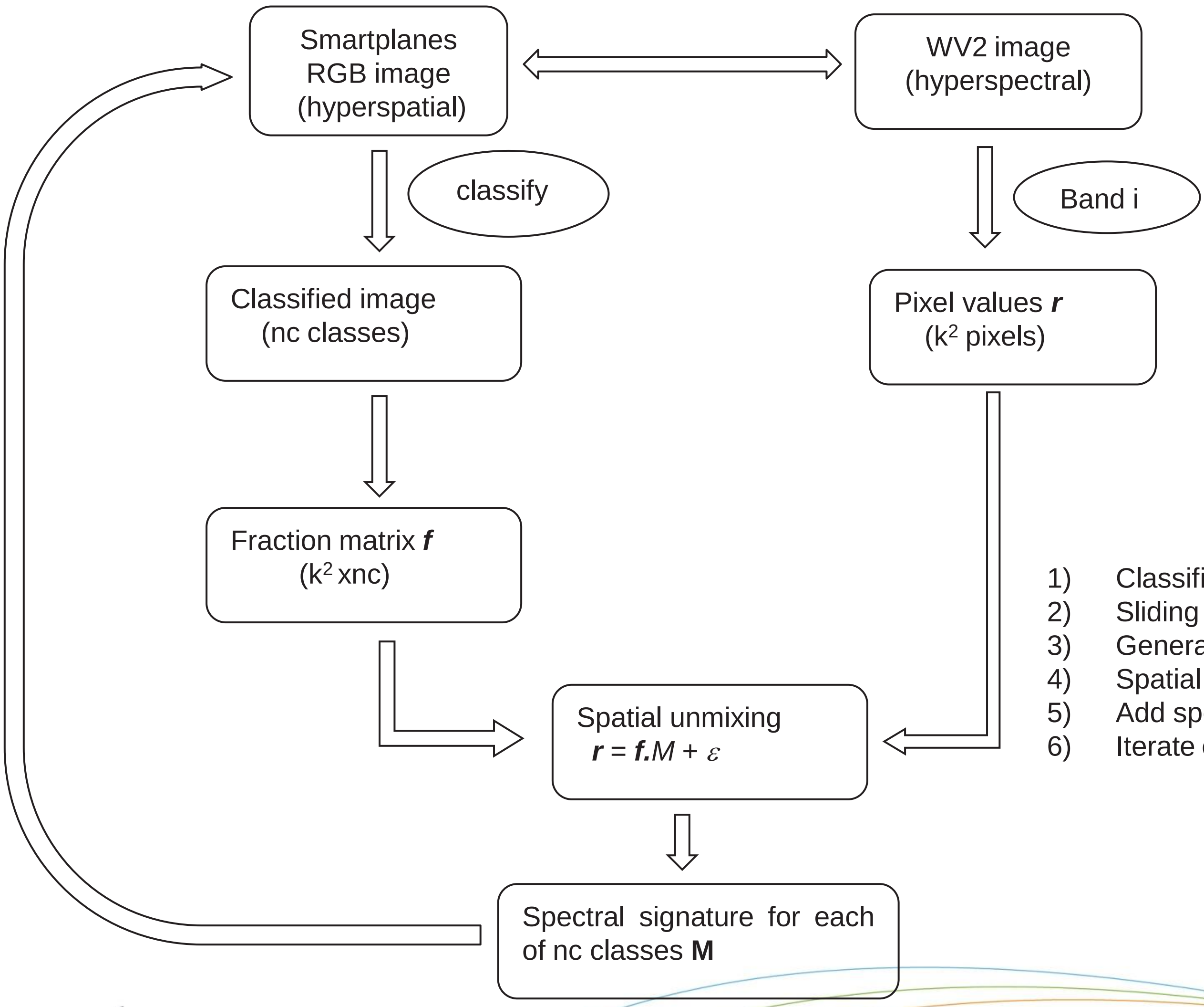


Data

» Smartplanes

WorldView-2

Methodology: unmixing based fusion Zurita-Milla et al., 2008



1) Classification of RGB
2) Sliding window size WV2
3) Generate class proportion matrices
4) Spatial unmix for each band
5) Add spectral signatures to central pixel
6) Iterate over all bands, whole image

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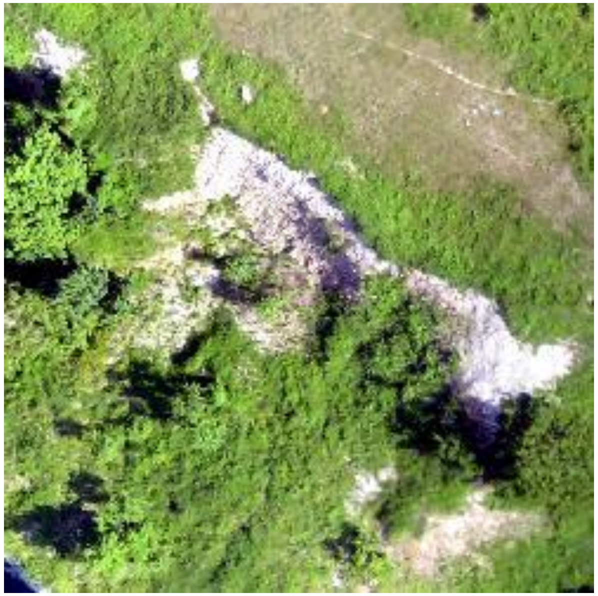
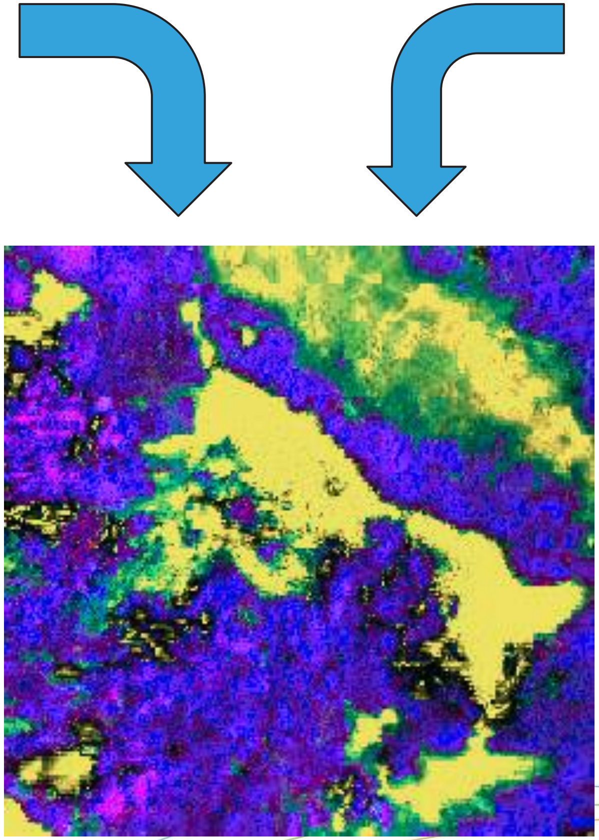
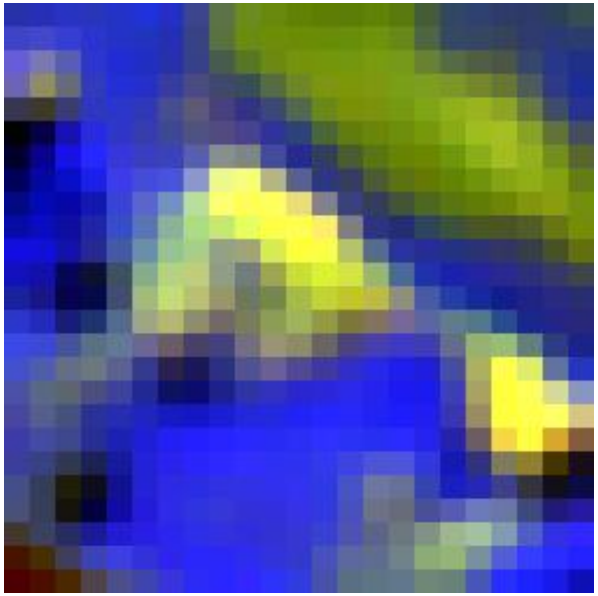
Results : unmixing based fusion







Preprocessing :

Spatial resampling

0,05m → 0,2 m

equalize image quality
limit resolution gap

Result:

8 spectral bands

0,2 m spatial resolution