Site Report: Mostar, Bosnia and Herzegovina

Amer Smailbegovic,

In cooperation with: Mirna Raic, Mak Kisevic, Marc Goosens, Roko Andricevic

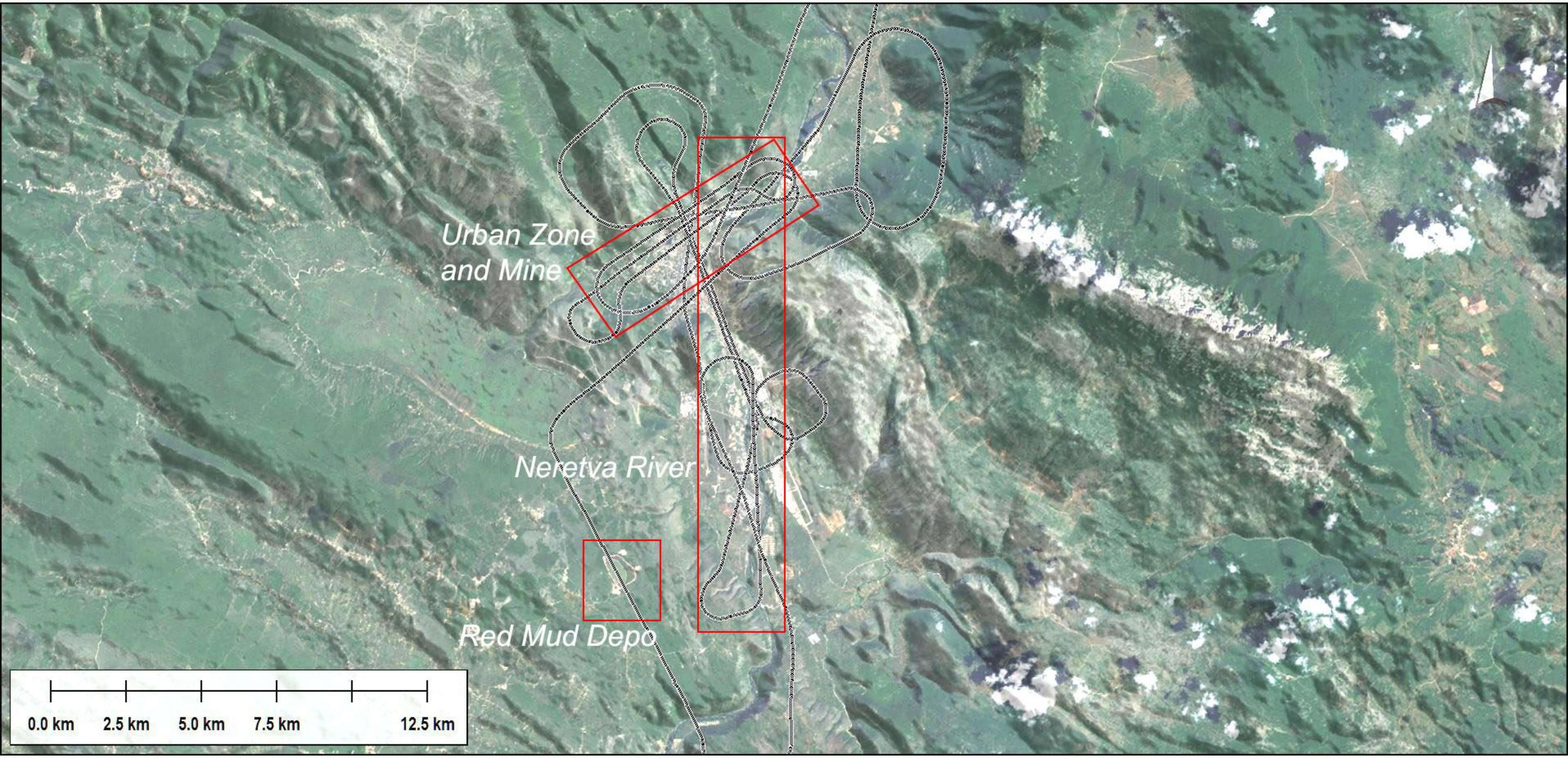
www.photonsplit.com
info@photonsplit.com

SEVENTH FRAMEWORK PROGRAMME

Plan of activities

- Overview of the entire Mostar Valley to determine the impact of mineral extraction/processing activities on the environment
- Primary target: Vihovici open pit mine (coal), located in the core of city of Mostar, abandoned and only partially remediated in 2010
- Other targets: Red mud depo at Dobro Selo, River Neretva, City of Mostar.
- Technology: airborne remote sensing, light-weight remote sensing, in-situ measurements, spectroscopy
- Complex integration of various data and risk assessment

Locations

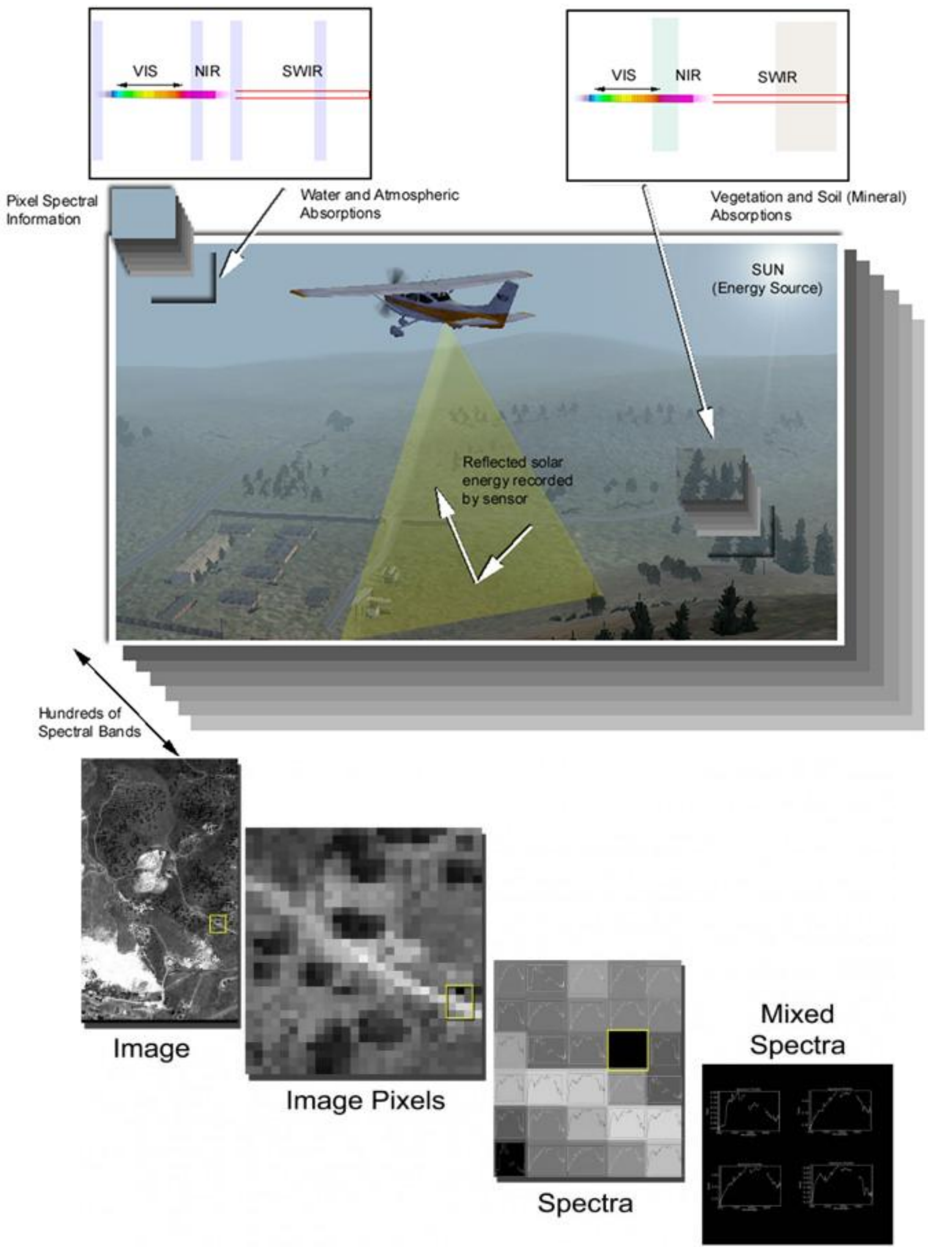


- Acquisition: 17-21 May, 2011 – combined methods of standard and light weight sensing and supporting in-situ measurements with approval from pertinent ministries and City of Mostar (end-user).
- Main hyperspectral overflight: 19 th of May, 2011 (1st HSI over BiH)
- In-situ measurements at the time of overflights

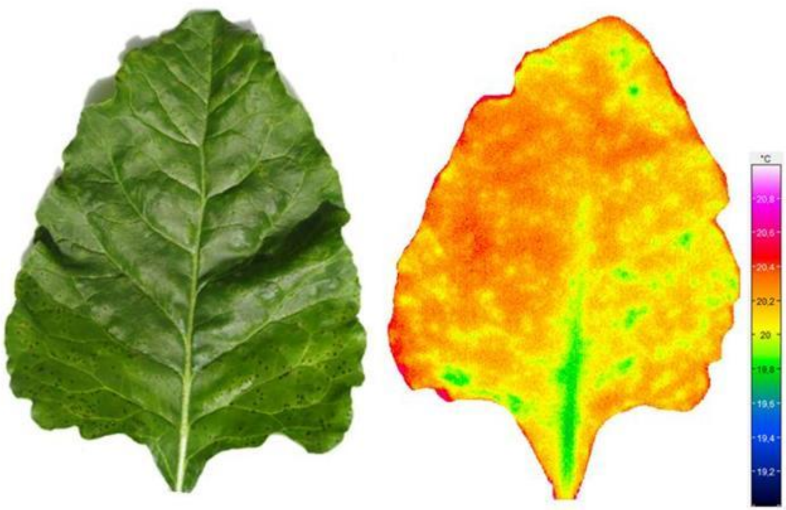
Part 1

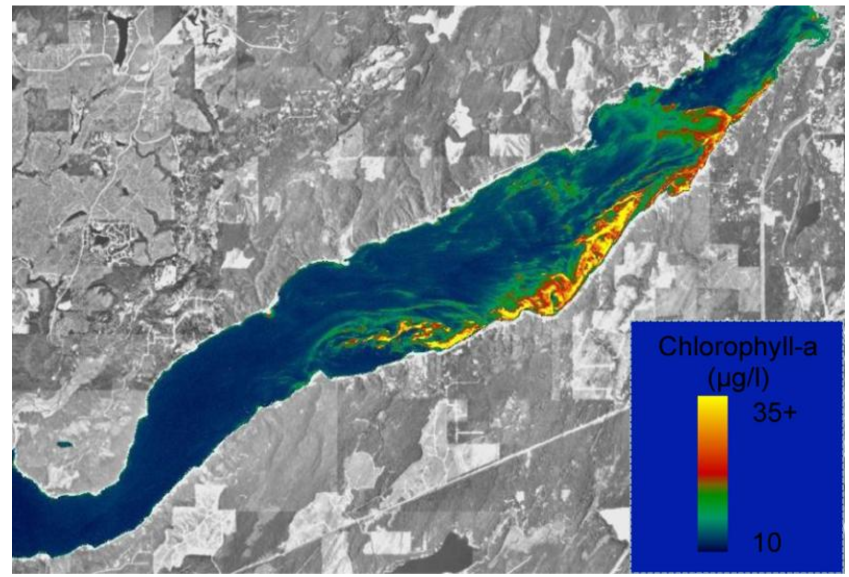
Airborne Operations

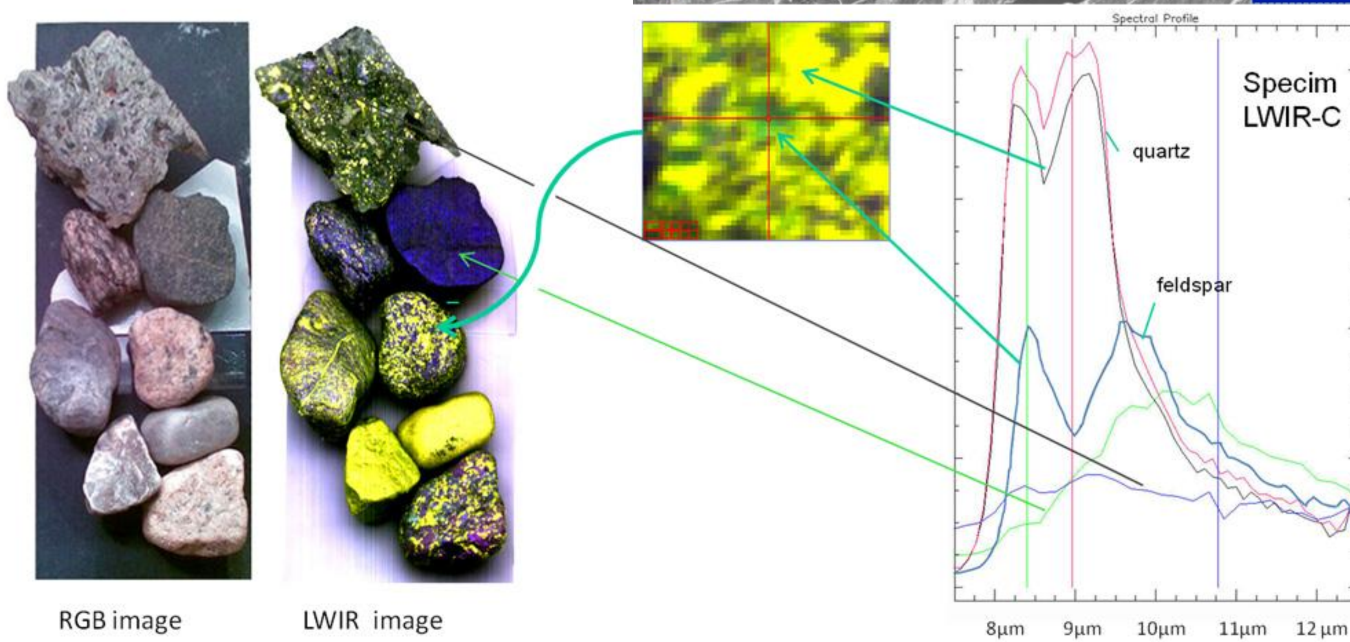
Hyperspectral Imager



Possibilities of Hyperspectral Detection







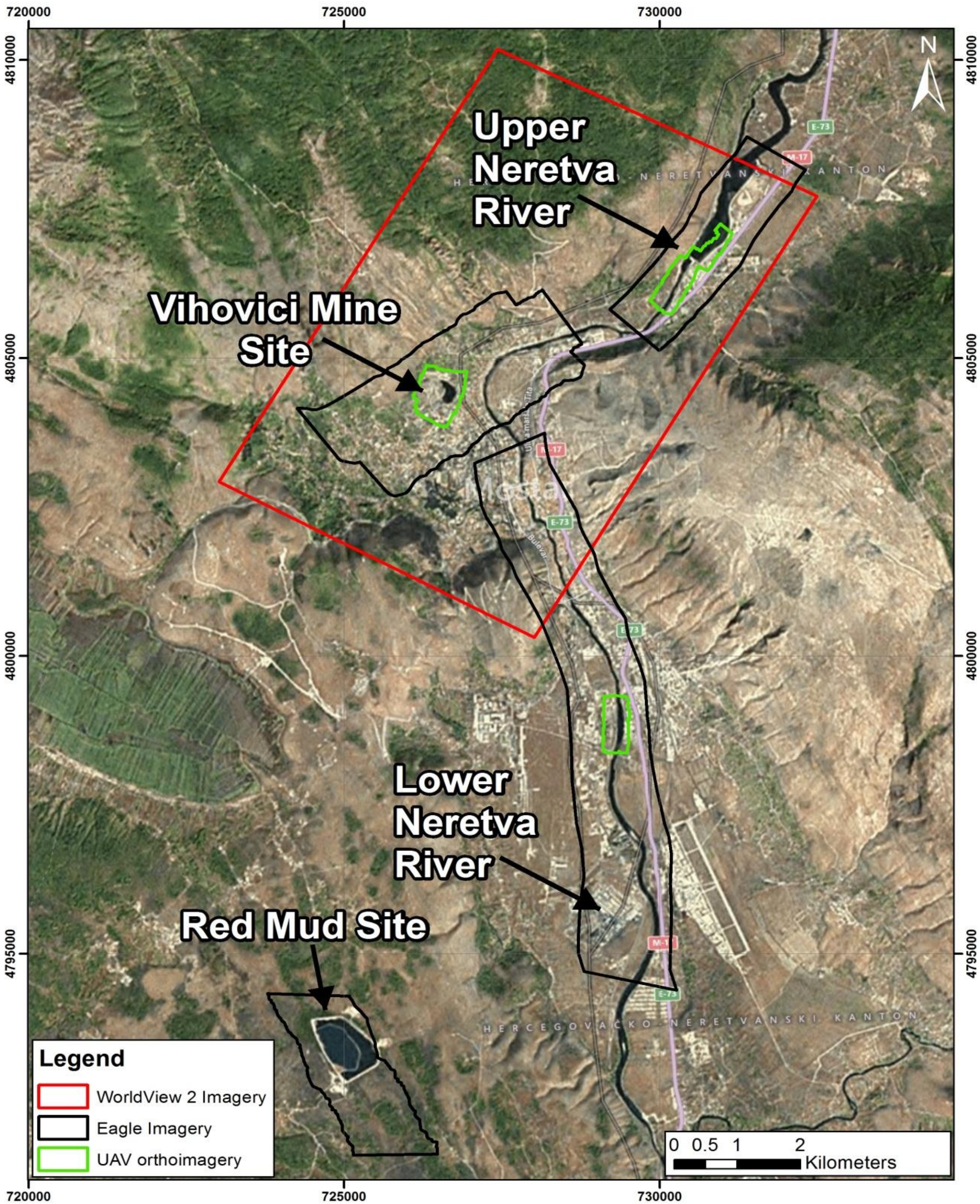

Vihovici, around 2008


Vihovici, 2008

Vihovici i Mostar, today

Mostar from the air, 5/19/2011

Mostar from the ground, using Smartplanes^{tm} UAV



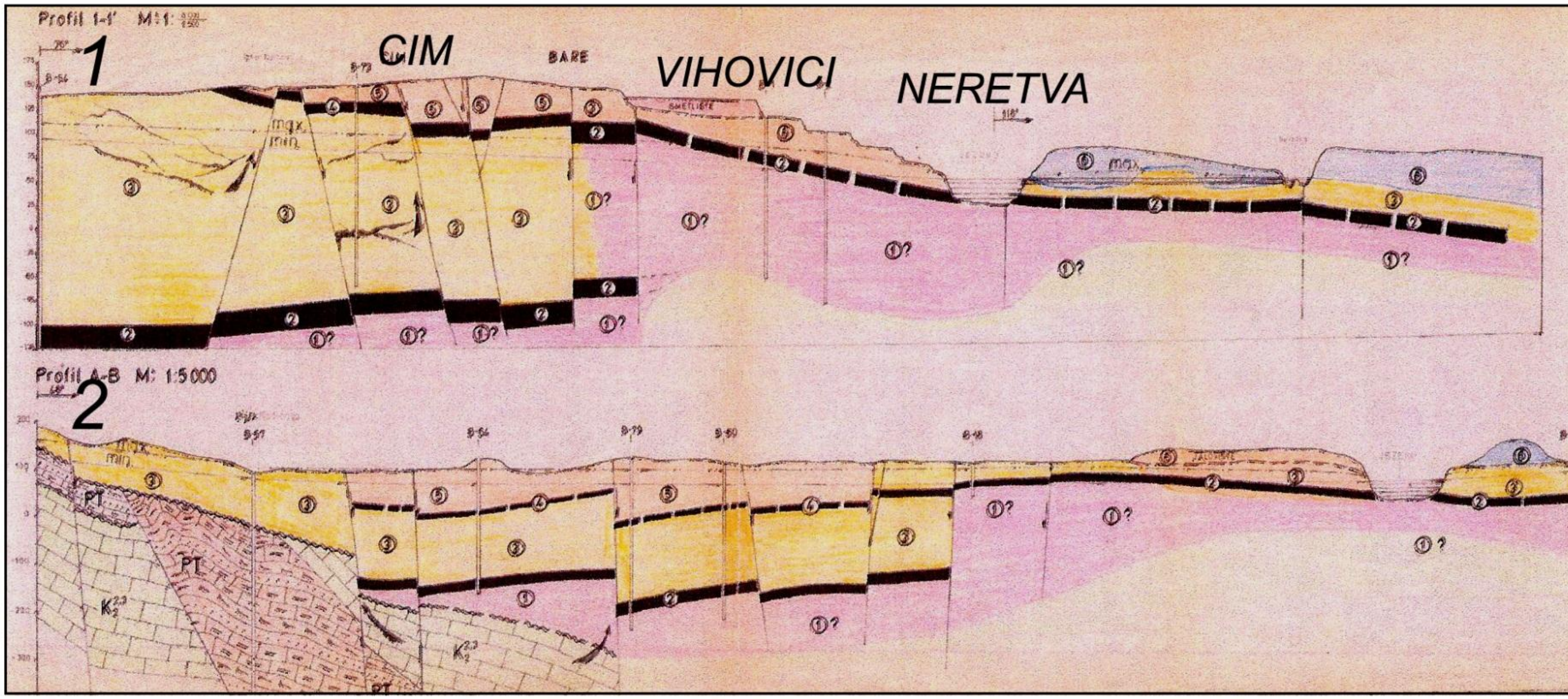
Around 300 GB of data was collected at Mostar during airborne campaign using Eagle II hyperspectral imager and SmartPlanes tm UAV.

The data were analyzed to measure and indicate:

- Types of surface minerals present in the given locations
- Water quality
- Vegetation health
- Geotechnical elements
- Waste (municipal/household) accumulations (illegal).

www.photonsplit.com
info@photonsplit.com

Geology of Vihovici



Quaternary

Excavated overburden, conglomerates alluvium/colluvium

Neogene

Hanggin wall of the top coal seam (marl, limestones and sandstones)

Top coal seam - impermeable

Hanging wall of the main coal seam (limestones to conglomerates) permeable - to non-permeable

Main coal seam - impermeable

Footwall of the main coal seam (marl and limestone) - impermeable in complex

Paleogene

Flysch (marl-sandstone-conglomerate) Impermeable

Limestones - permeable

Brown-gray limestones permeable

Cretaceous

Rudistic limestone - permeable

Sandstone, schist, marl, limestone impermeable

Highest

Lowest groundwater

Monitoring piezometer

Groundwater flow direction

Geology, how acid-waste is formed

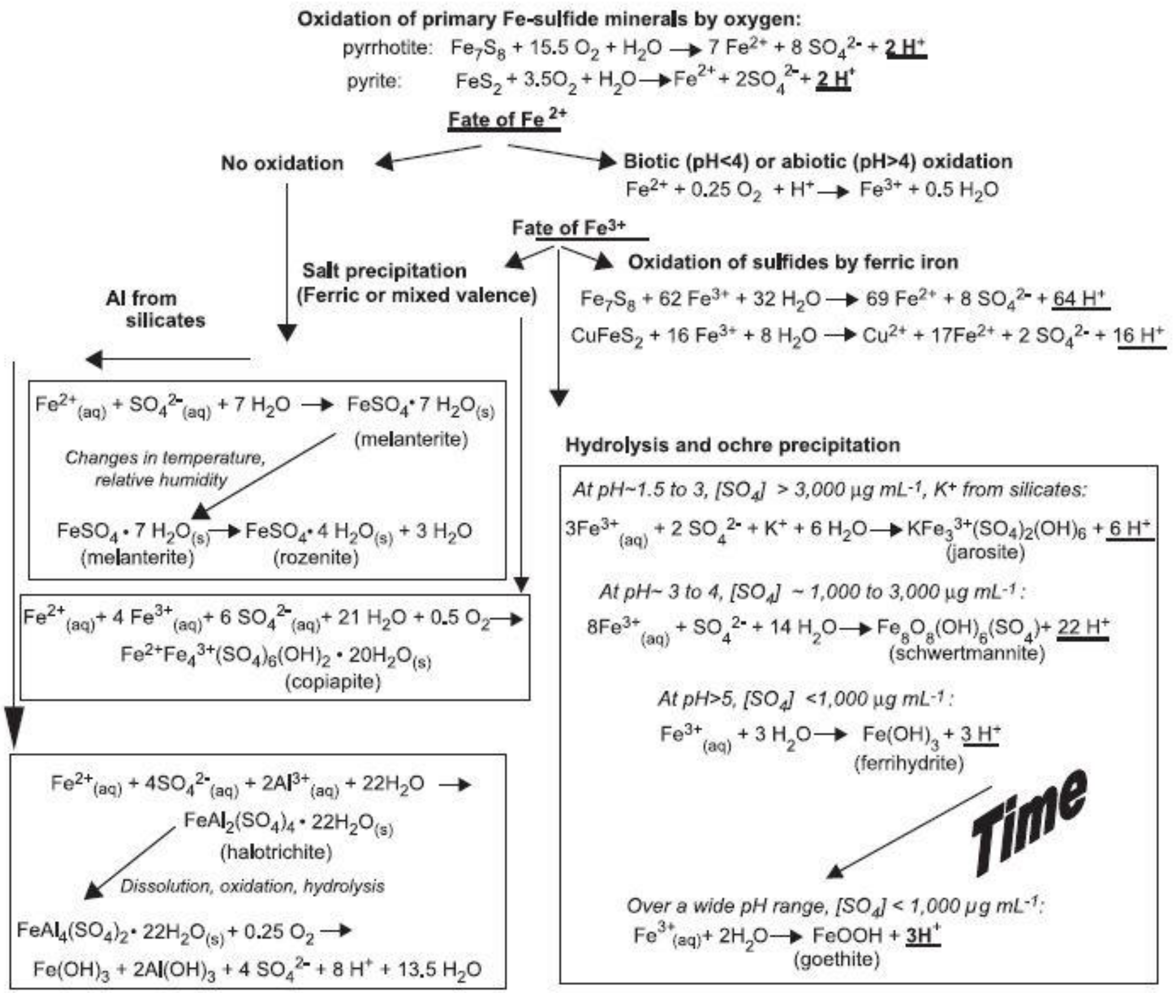
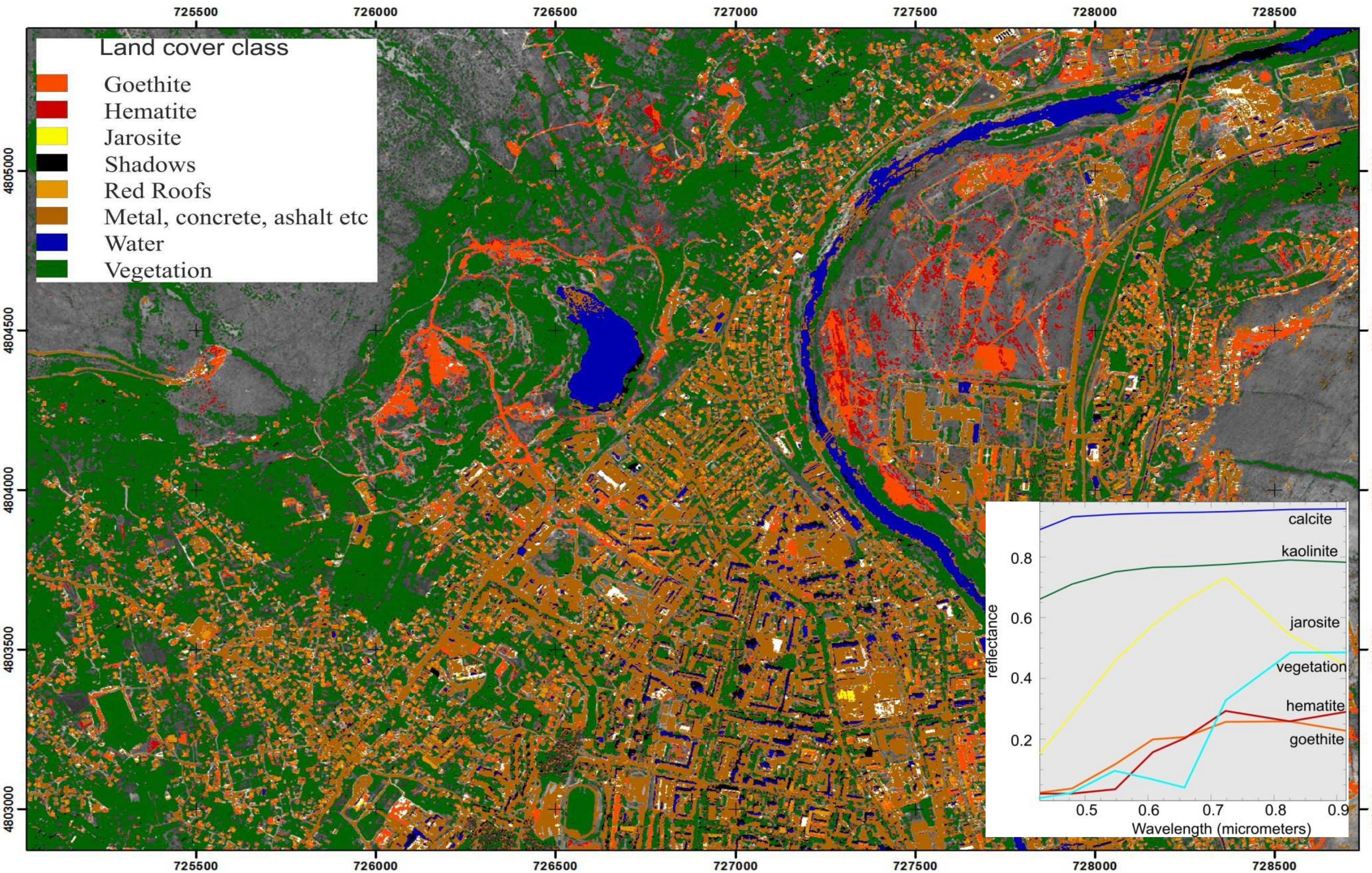


Fig. 3. Processes that lead to secondary sulfate-mineral formation from oxidation of primary Fe-sulfide minerals. Acid-generating steps are underlined. Reactions based on those of Scharer et al. (1994), Bigham (1994), Plumlee (1999), Rose and Cravotta (1998), Bigham and Nordstrom (2000), and Jambor (2003).

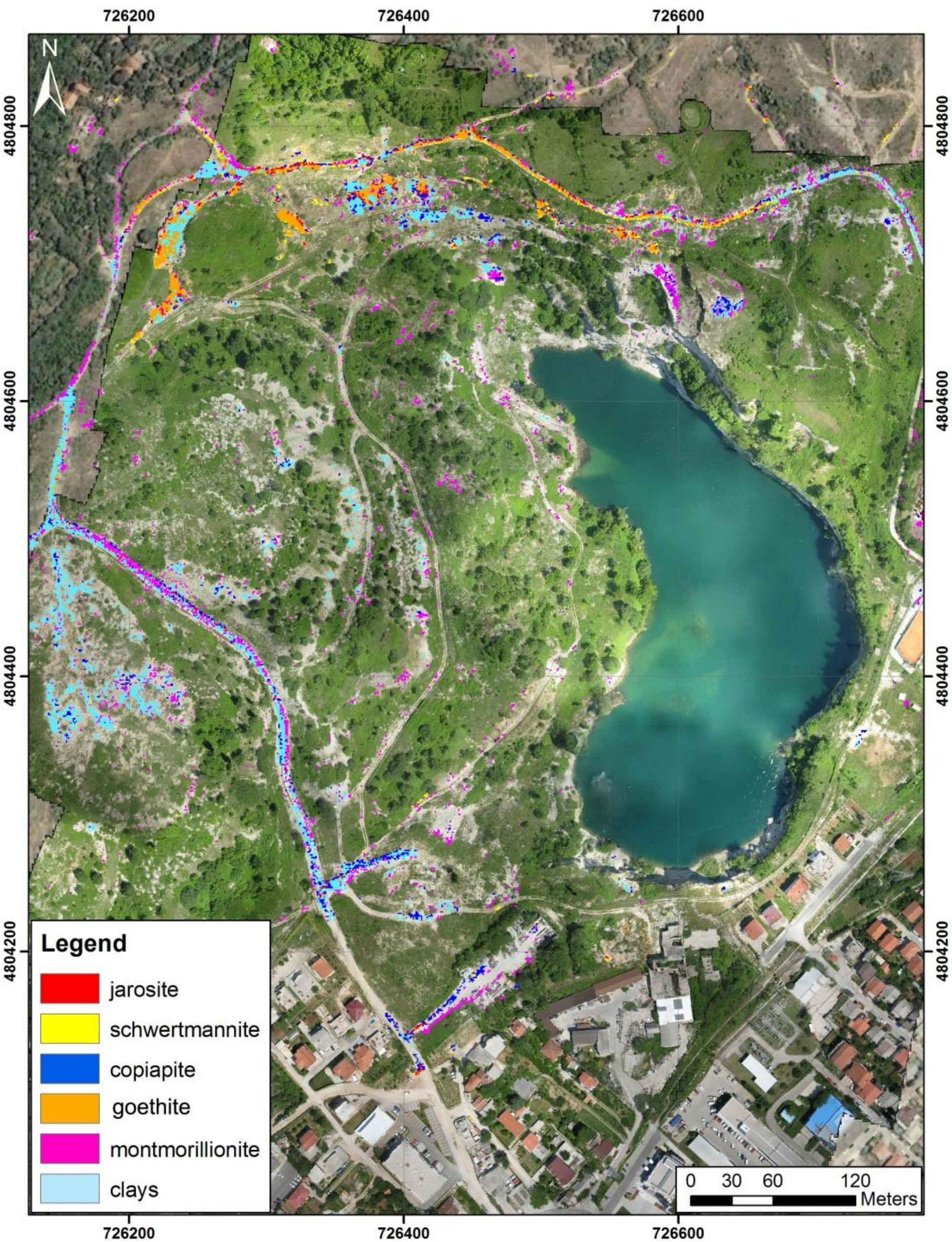
Mineralogical Data

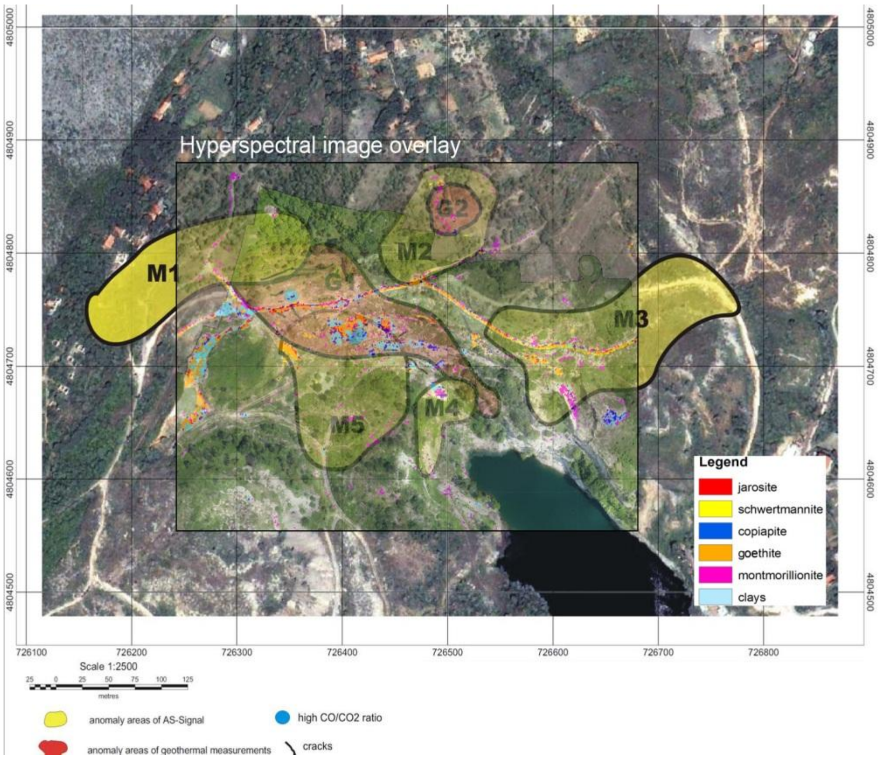
Worldview 2 Satellite



Mineralogical Data

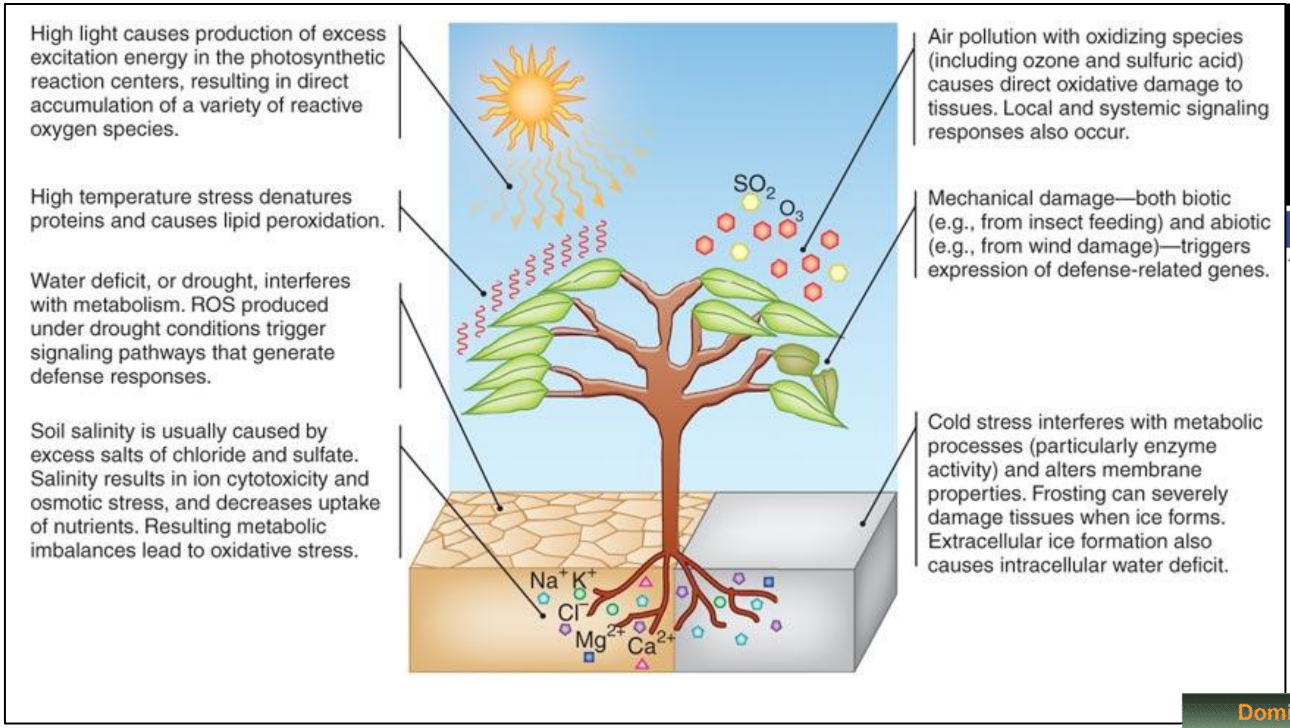
Hyperspectral Sensor Eagle II

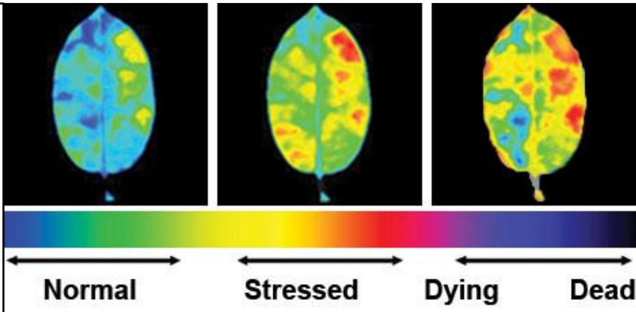


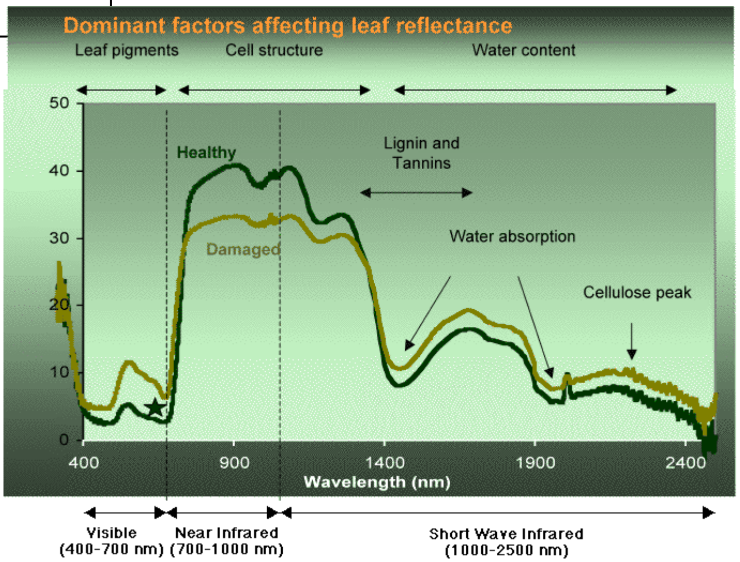


Increase concentration of iron sulfates on the northern rim of the mine.
Possibly formed as a result of uncontrolled coal burning prior to 2010
Minor concentrations noted on the fringes of old waste piles or industrial waste heaps in the east

Vegetation Stress



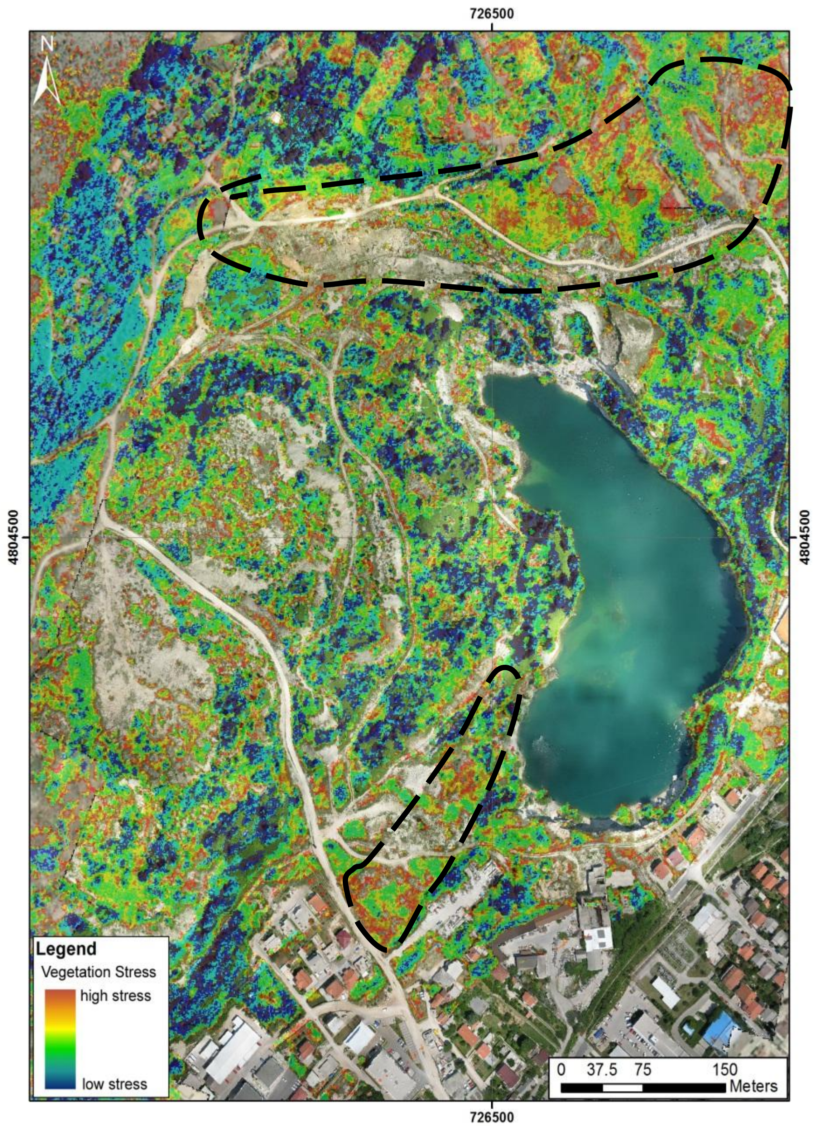


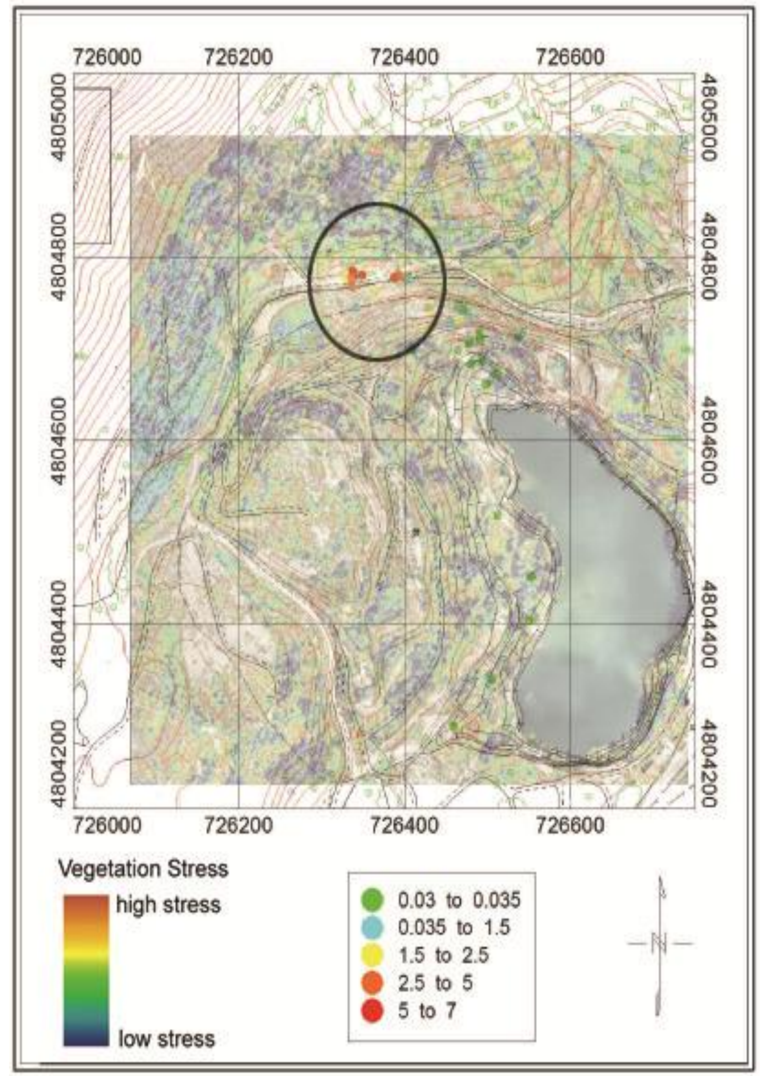


- Vegetation stress is usually related to some external factor deleterious to the health of the plant
- Stress can be noted in the infrared regions of the spectrum before it is visible to the unaided eye

Vegetation Stress

Hyperspectral data





Areas of vegetation stress correspond with the zones of former ore crushing (south) and burning regions (north) – note spread (downwind) of CO2 and H2S and vegetation stress


CO2 – H2S emission

Bigger problem are the illegal dumps of household and industrial waste…

Using high-resolution imagery from Smartplanes[tm] UAV it is possible to discern some of the accumulations of household waste.

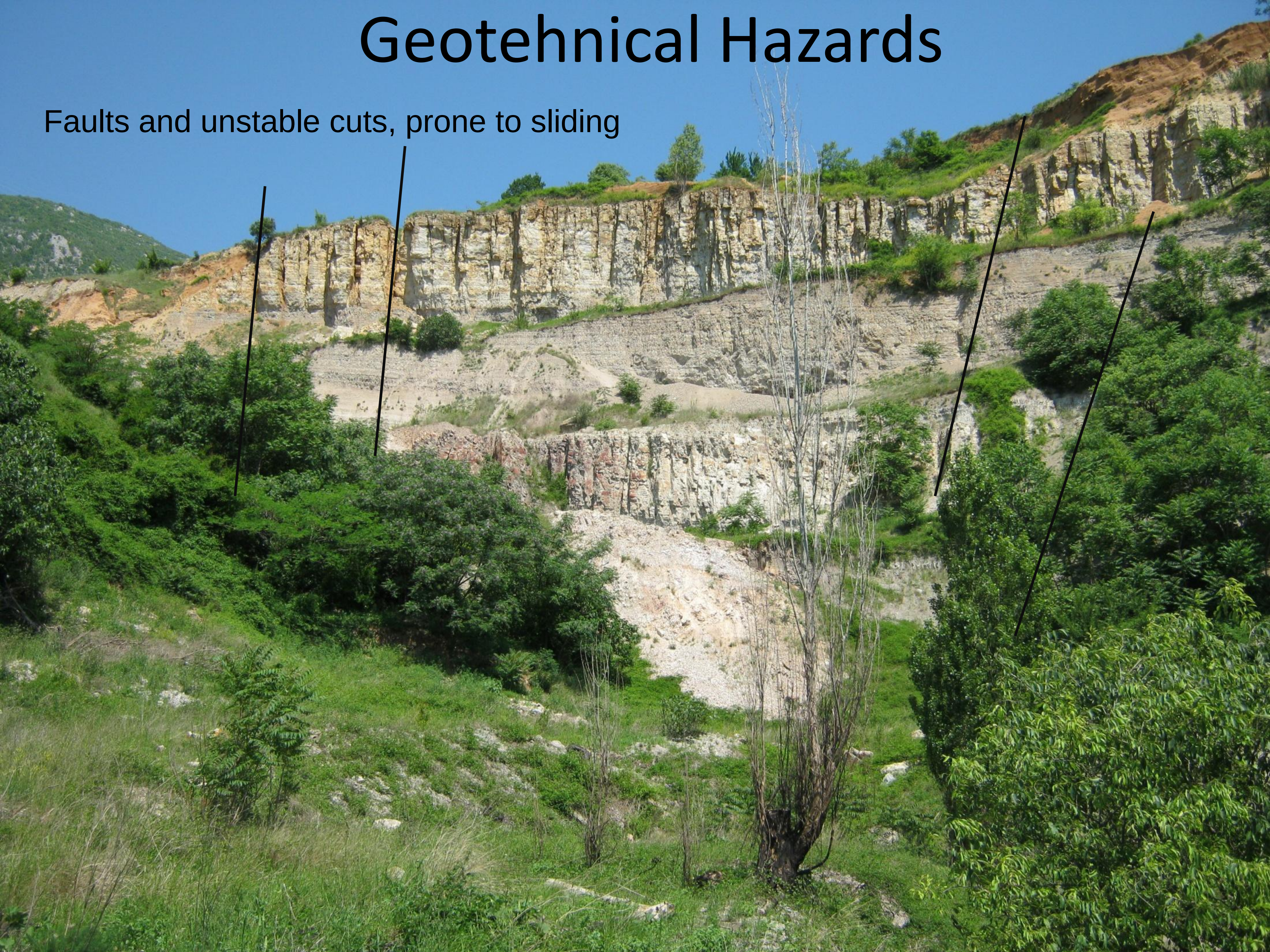
Waste

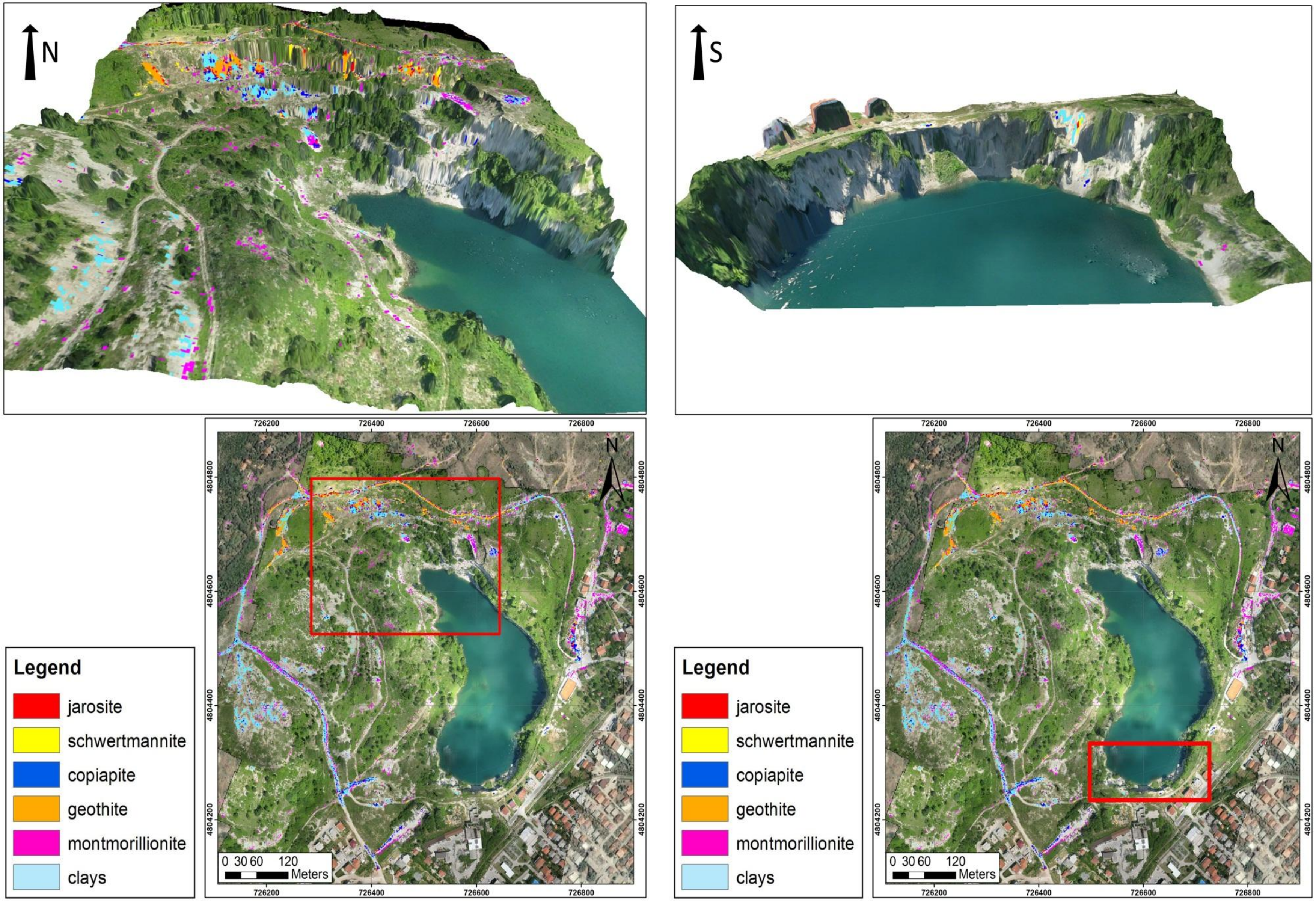
Concentrations of household waste noted on the high-resolution imagery as well as hyperspectral data.

These accumulations formed from 2010 to present day and are growing considering no access control to the mine.

Problem that needs to be addressed before area returns to state before 2007

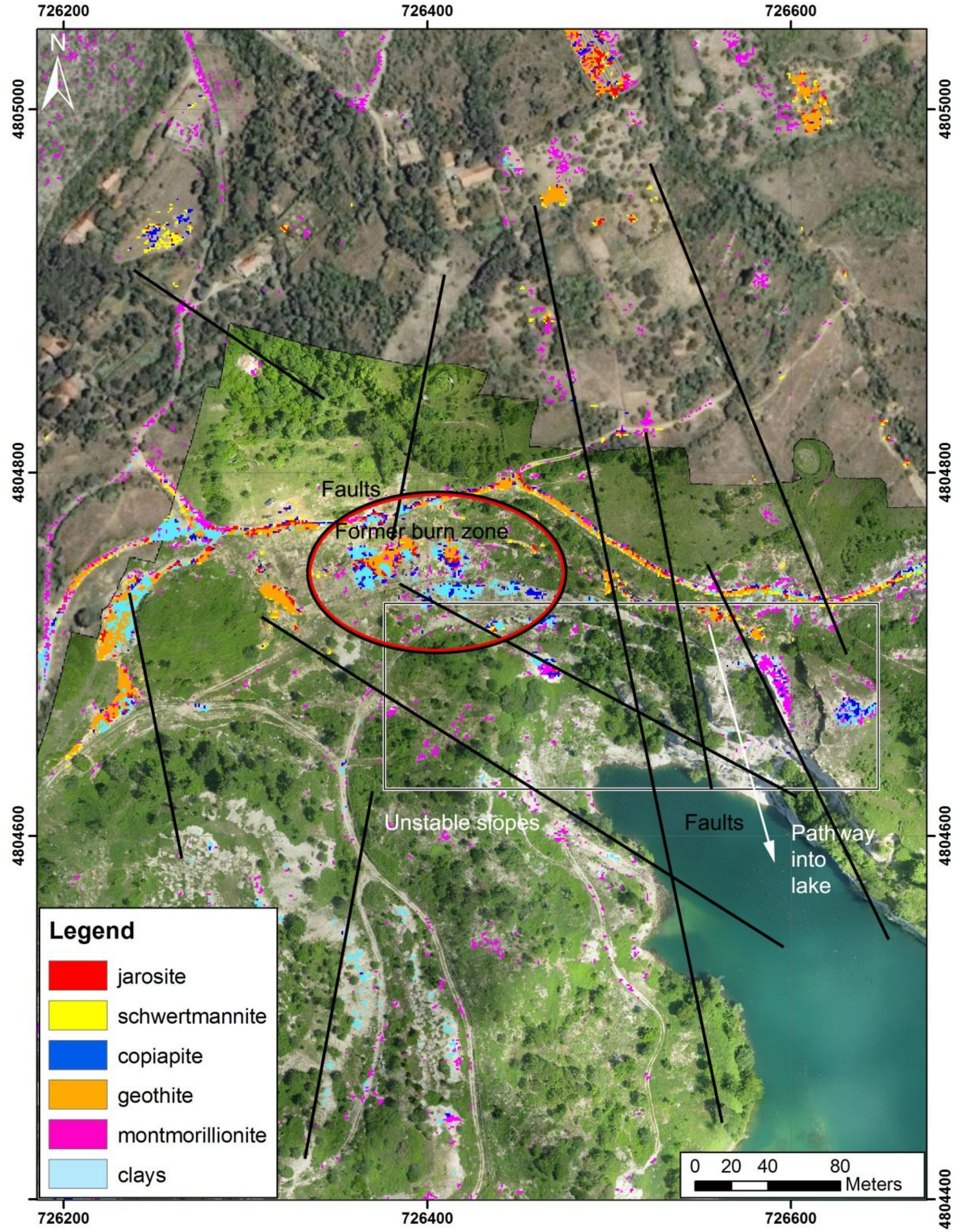
Geotehnical Hazards





Combined hyperspectral and Smartplanes tm UAV imagery showing areas of expansive clays in the northern and southern flanks of the Vihovici pit/lake. Clay minerals are most problematic as they may swell and increase mass by over 200%.

Some of the observed slopes are in an extremely unstable conditions and are in imminent possibility of collapse, possibly along the planes further weakened by weathering and burning.



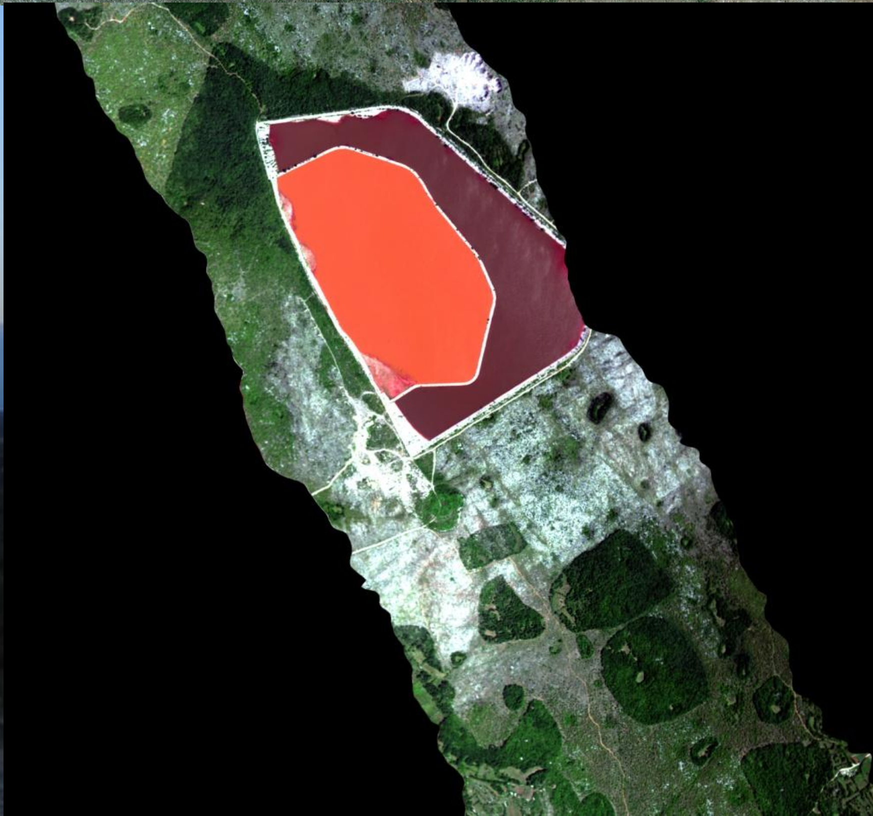
Simulated scenario of pit breach

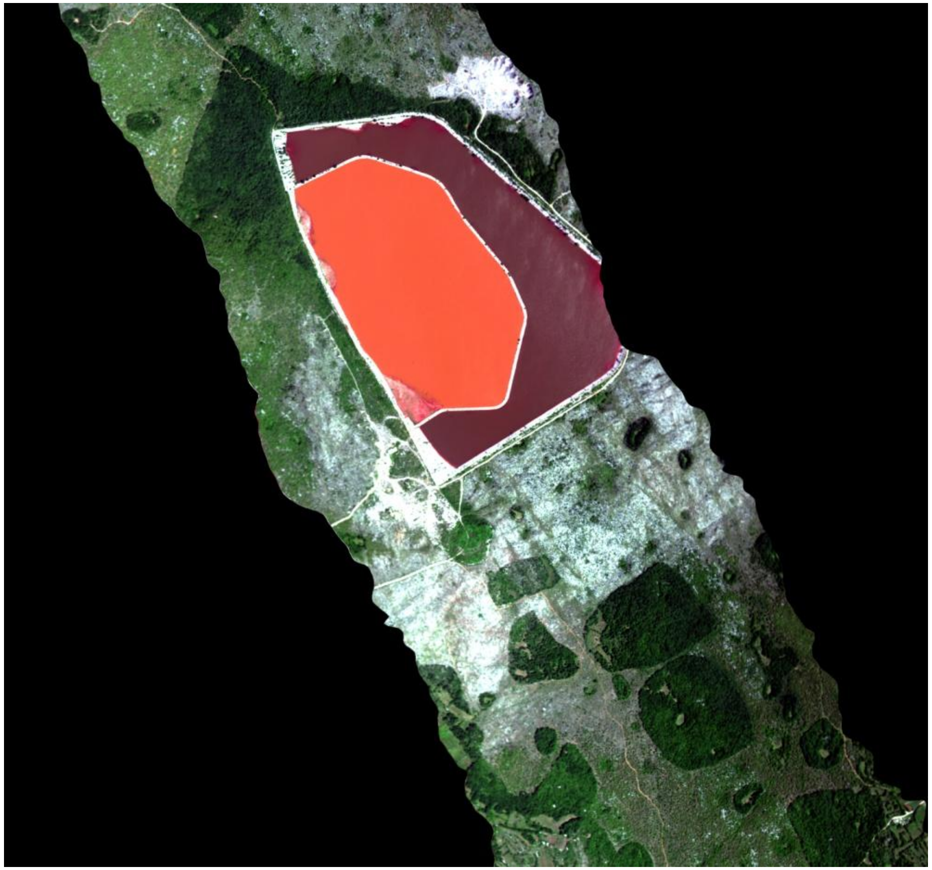
(based on collapse of the northern wall into the lake)

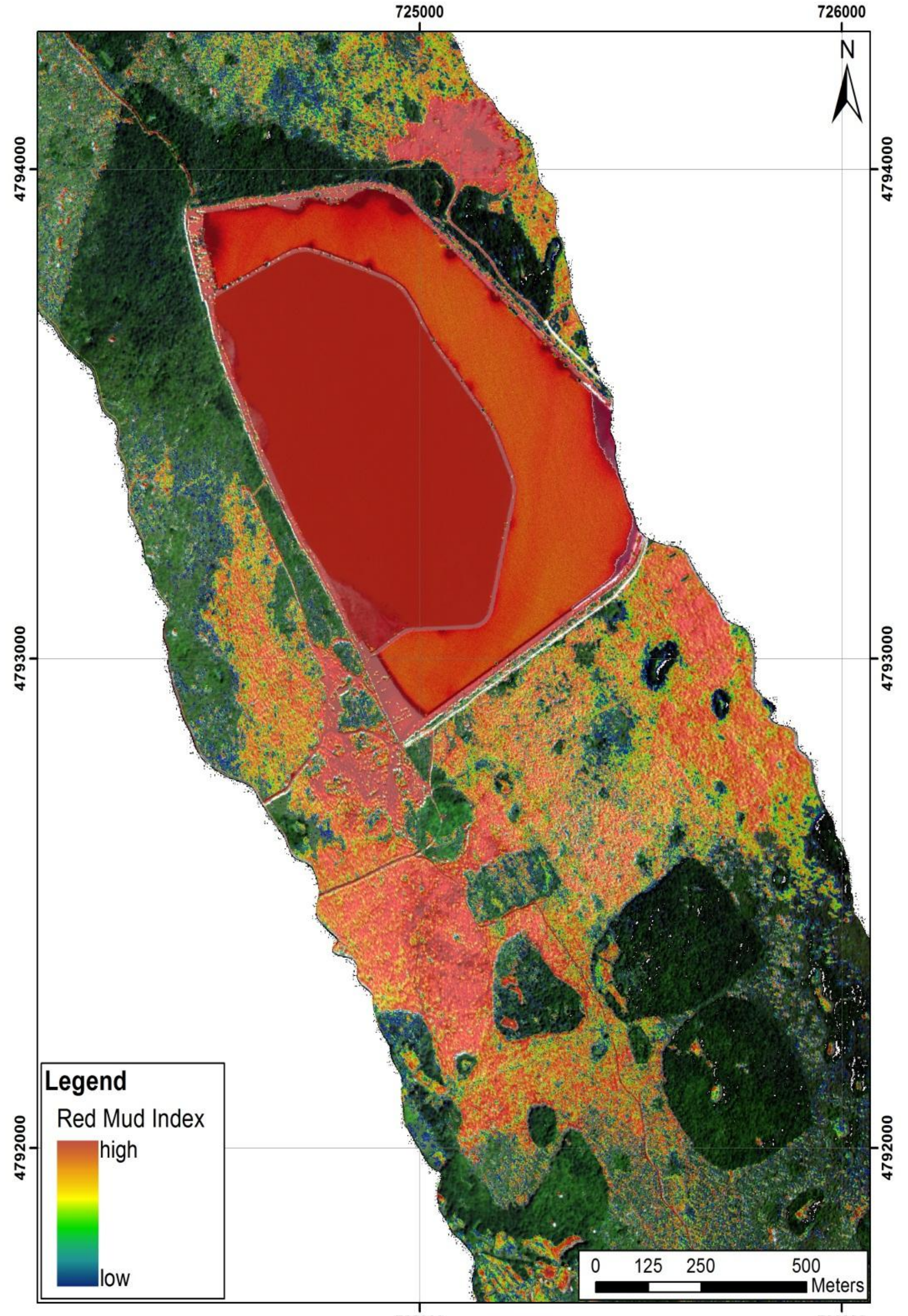
Large volume of water and material may surge out of the ruptured pit

Red Mud Depo Area Dobro Selo

Inactive since 1992

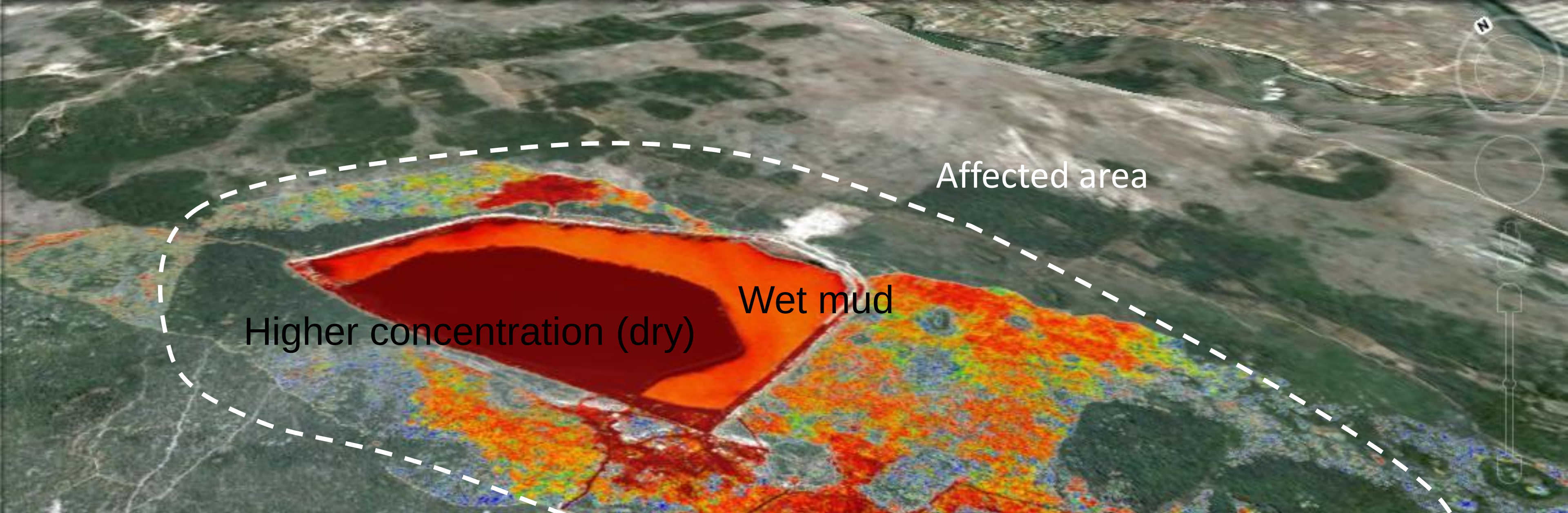
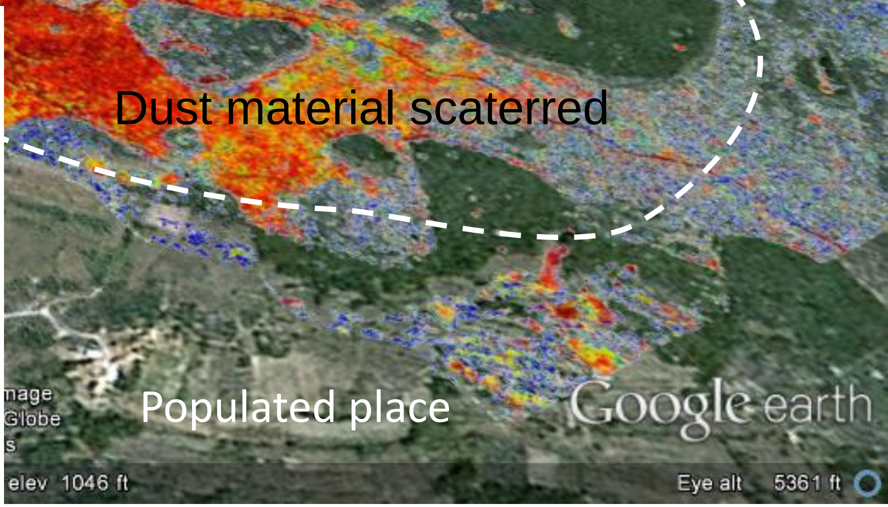


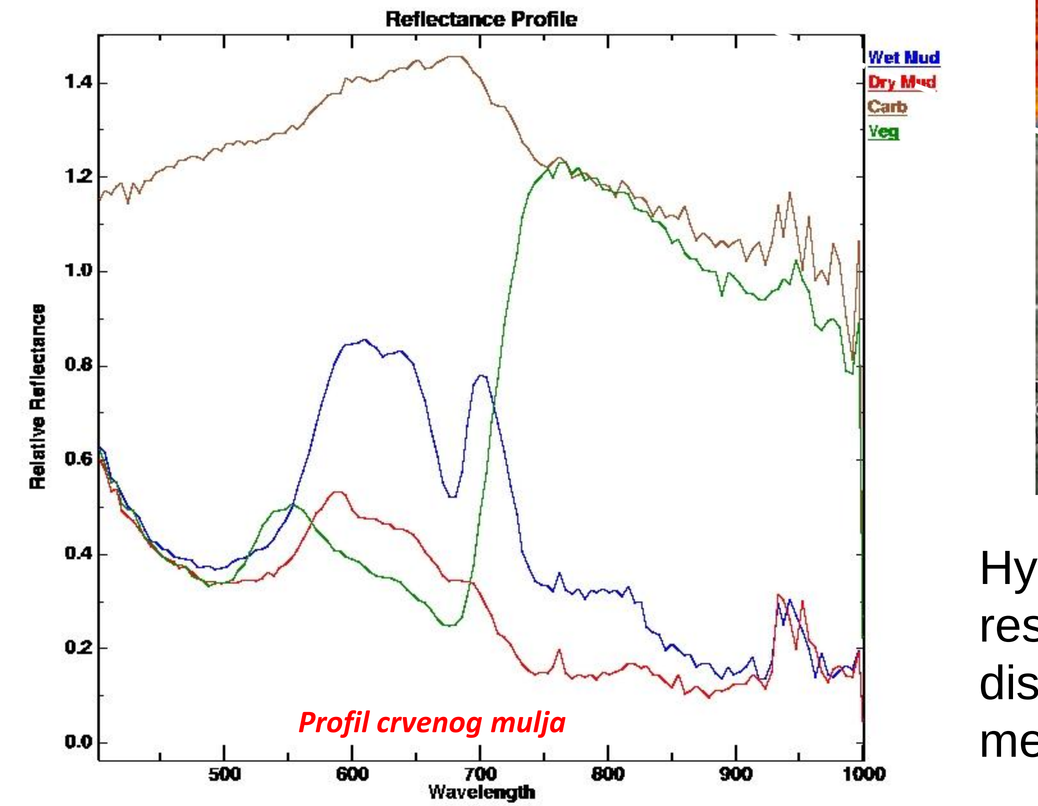




Hyperspectral data analyzed using red-mud reflectance index (developed after Hungarian spill).

Data suggest that surface volumes of red mud (dry) from the pit are being scattered beyond the confines of the pit, mainly along the prevailing wind direction.



Hyperspectral data overlain on high-resolution GE imagery showing the dispersal of red mud along the axis of mesa upon which is located.


Part 2
Water Operations

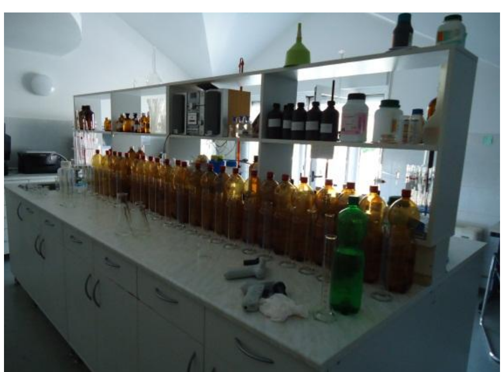
Sampling

60 locations visited and 47 samples collected

Sample Analysis

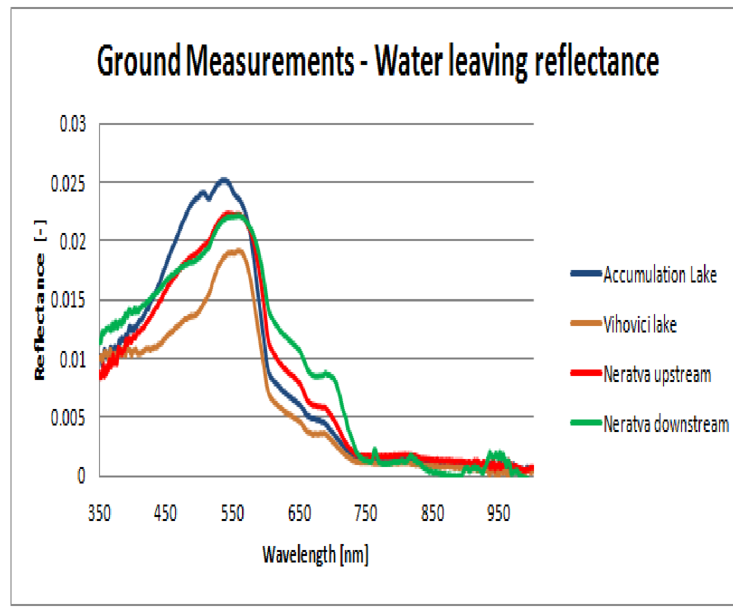
Laboratory Analysis

- Chl, TSS, turbidity, nitrites, nitrates, TN, TP, Cd, Pb, Fe, total PAH, PCB
- Institute for public health, city of Mostar, BH



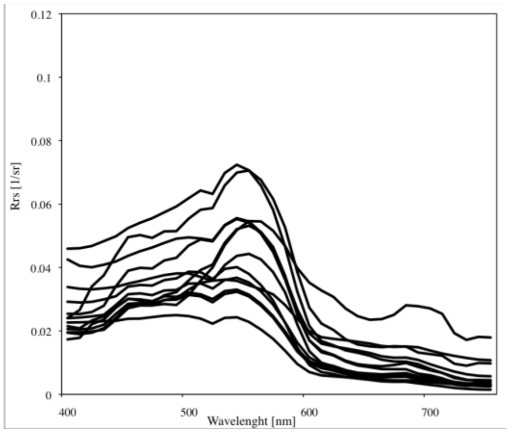
Spectral reflectance (in-situ)

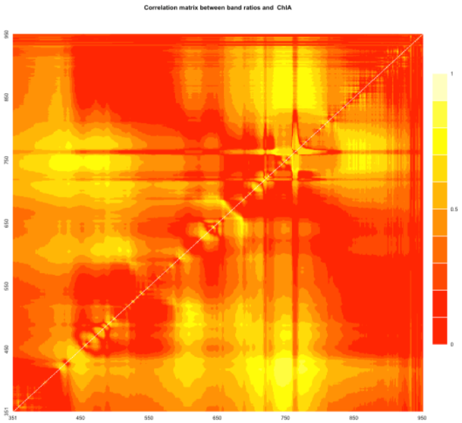
- Fieldspec spectrometer ASD – 350-2500 nm

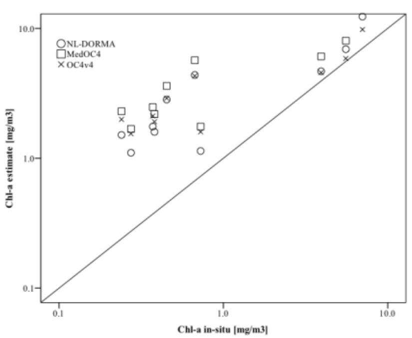


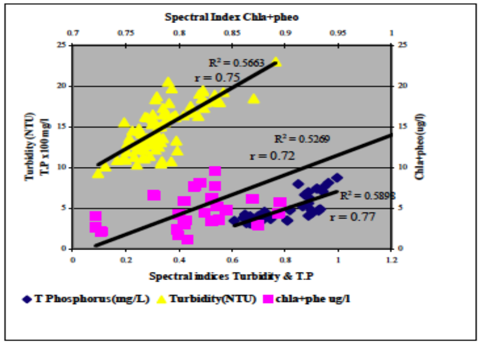
Correlation Search

- Looking for correlation between HSI and optically-visible elements in water: Chl, TSS, Turbidity (proxy for other elements)
- Observing spectrum between 350 nm and 1050 nm
- Using relationships between to wavelengths to determine correlations
- Based on the wavelength pairs with greatest degree of correlation, developed search and classification algorithms for water classificiation









Parameters (Y vs X)	Regression relationship	R^2
[Chl a] vs R443/R555	$Y = -7.075 \cdot \log_{10} - 0.089$	0.62
[Chl a] vs R490/R555	$Y = -7.656 \cdot \log_{10} + 0.399$	0.73
[Chl a] vs R510/R555	$Y = -12.656 \cdot \log_{10} + 0.374$	0.79
[Chl a] vs R532/R555	$Y = -25.223 \cdot \log_{10} + 2.60$	0.74
[Chl a] vs R683/R555	$Y = 2.353 \cdot \log_{10} - 5.205$	0.26

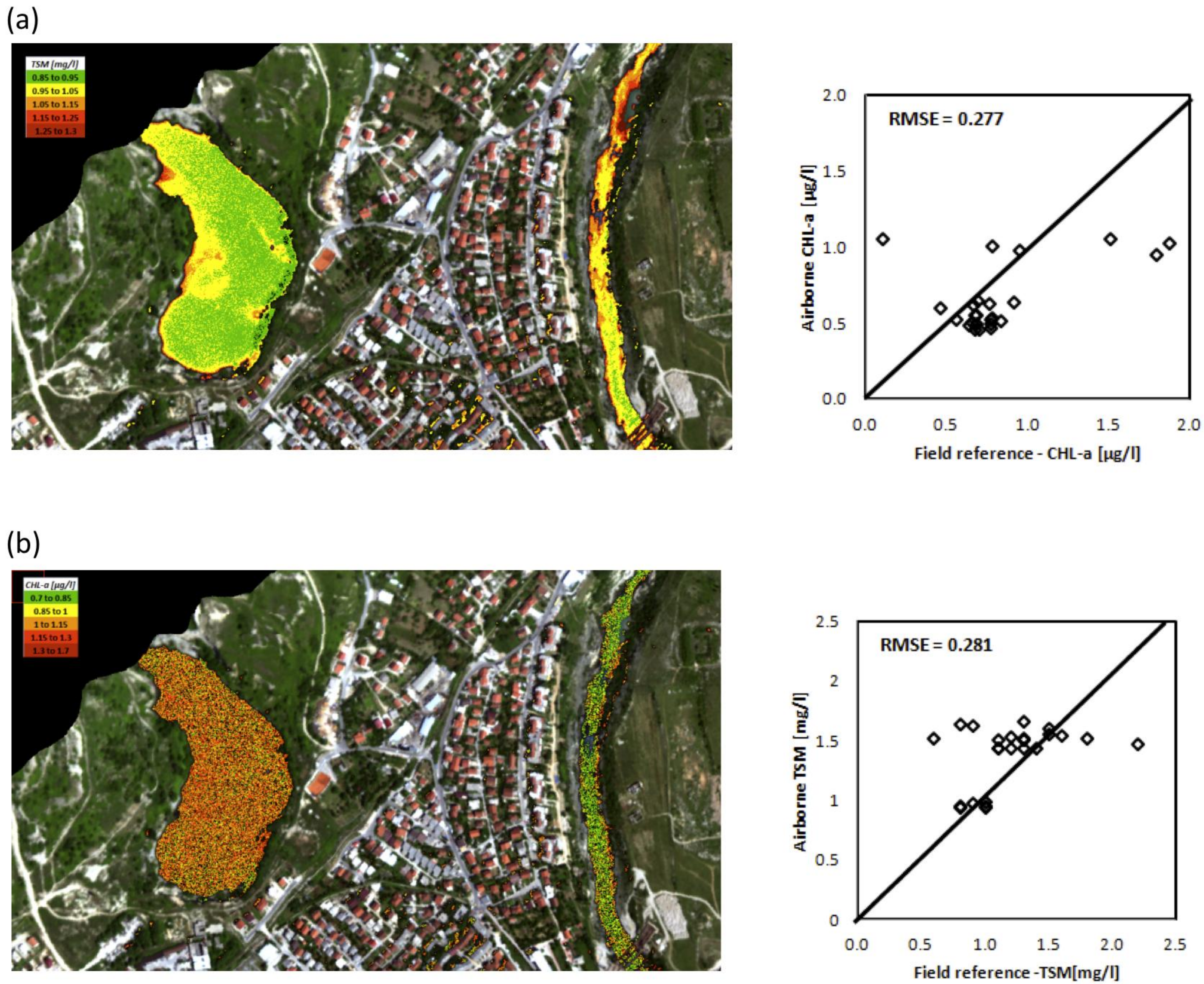


Figure 1 - Results of the Mostar Water quality map and ground validation: TSM and Chl-a.

Neretva River

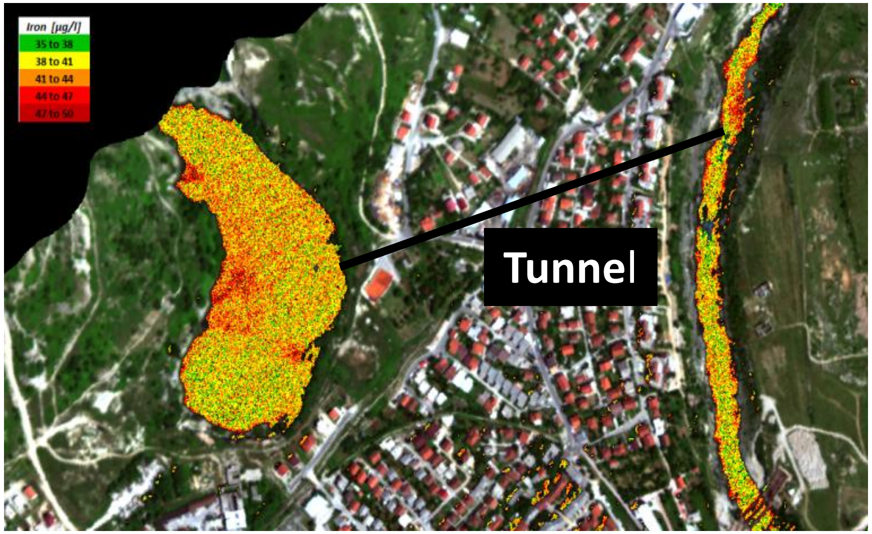
TSS

Biggest polluter is possibly (relatively) the City of Mostar

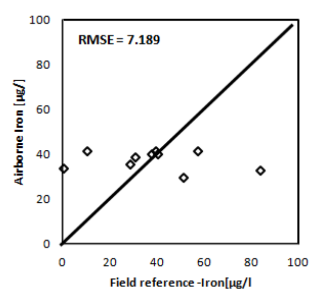
Chl

Last week collectors and separators were put in use by the City.

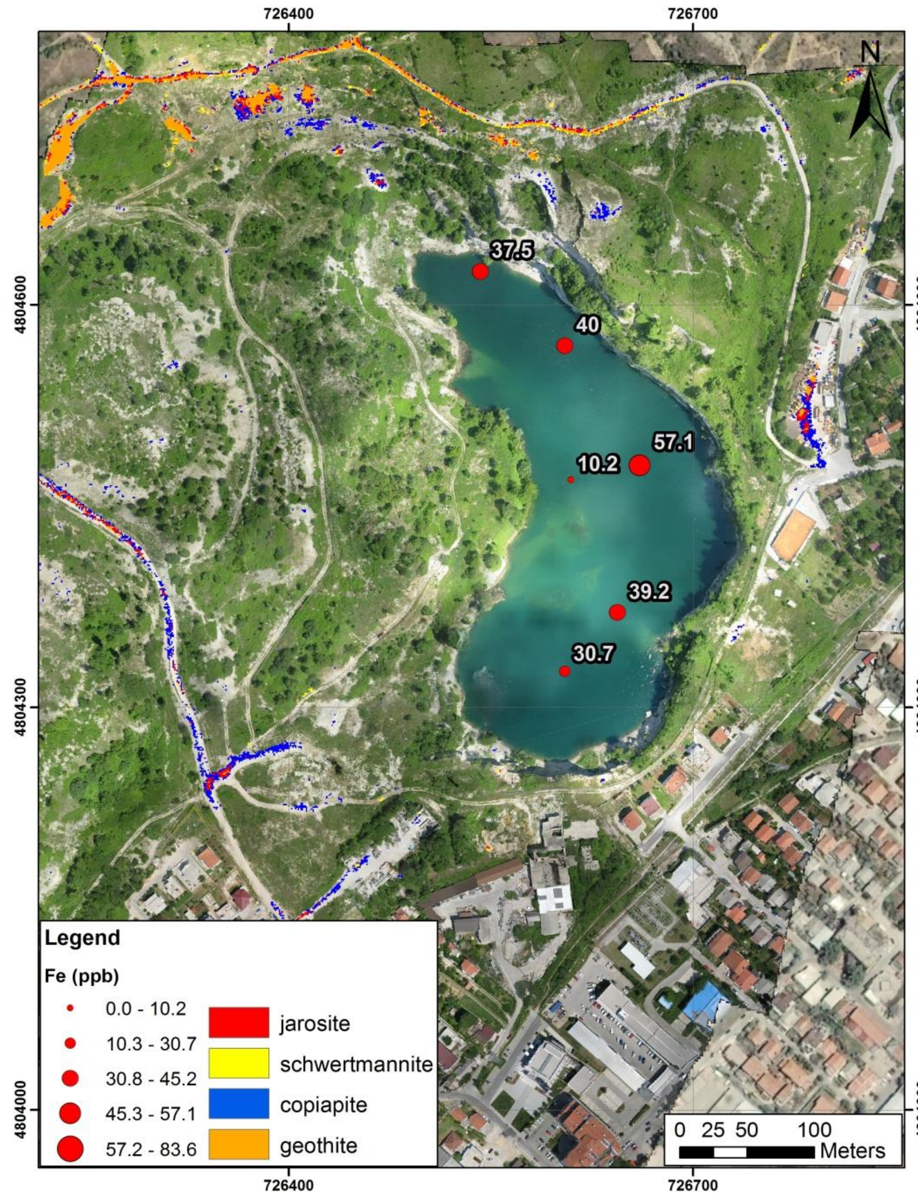
Correlation of HSI and Chemistry



HSI data suggest some correlation between increase Fe in water samples and abundance of surface Fe minerals and approximate area where mine and pit lake are conjoined by the submerged tunnel.



R > 0.6



Chlorophyll and Nitrate

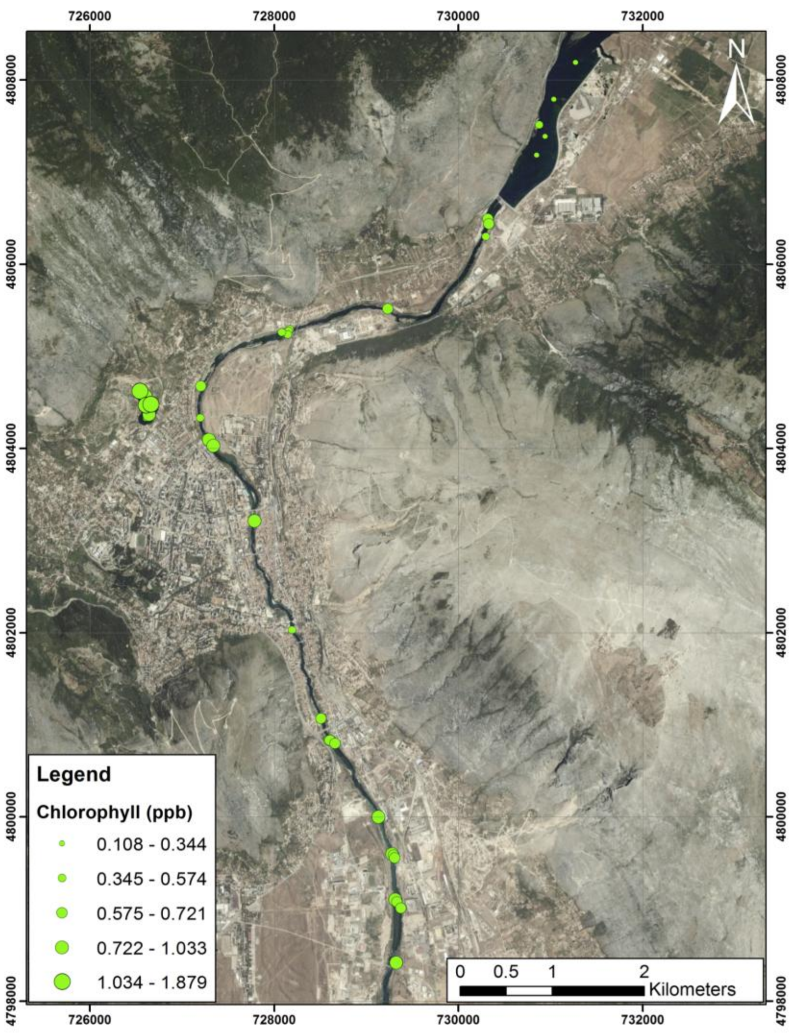
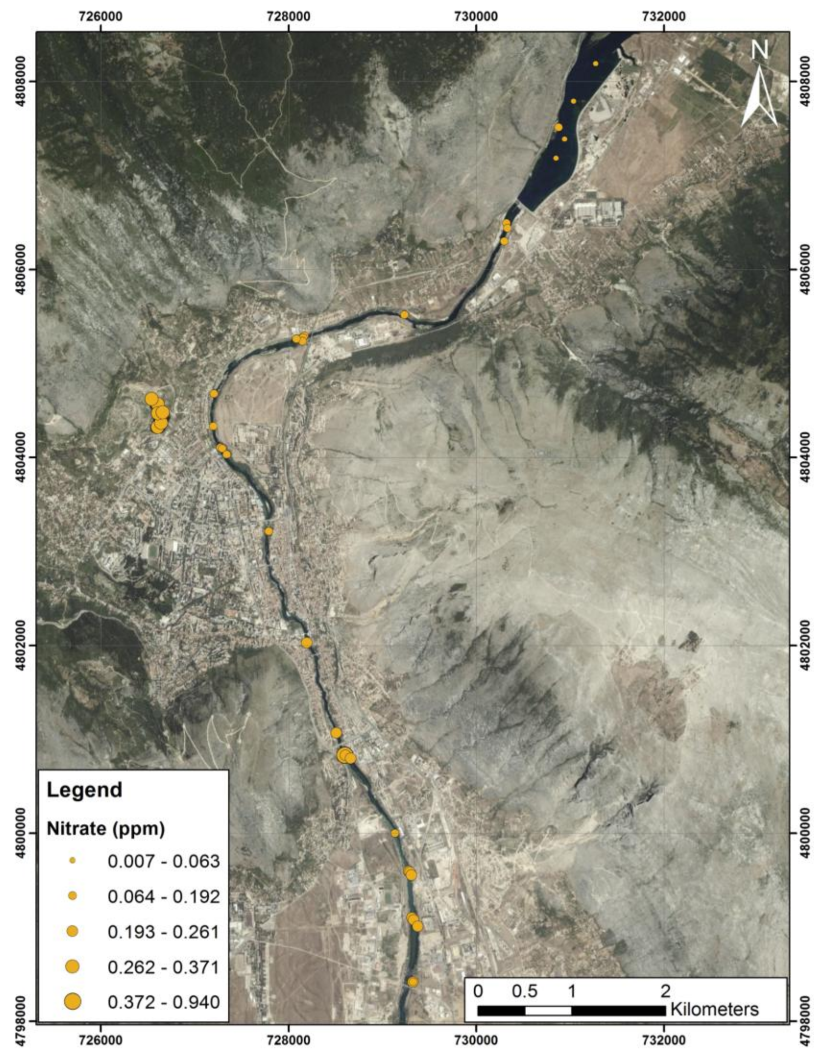
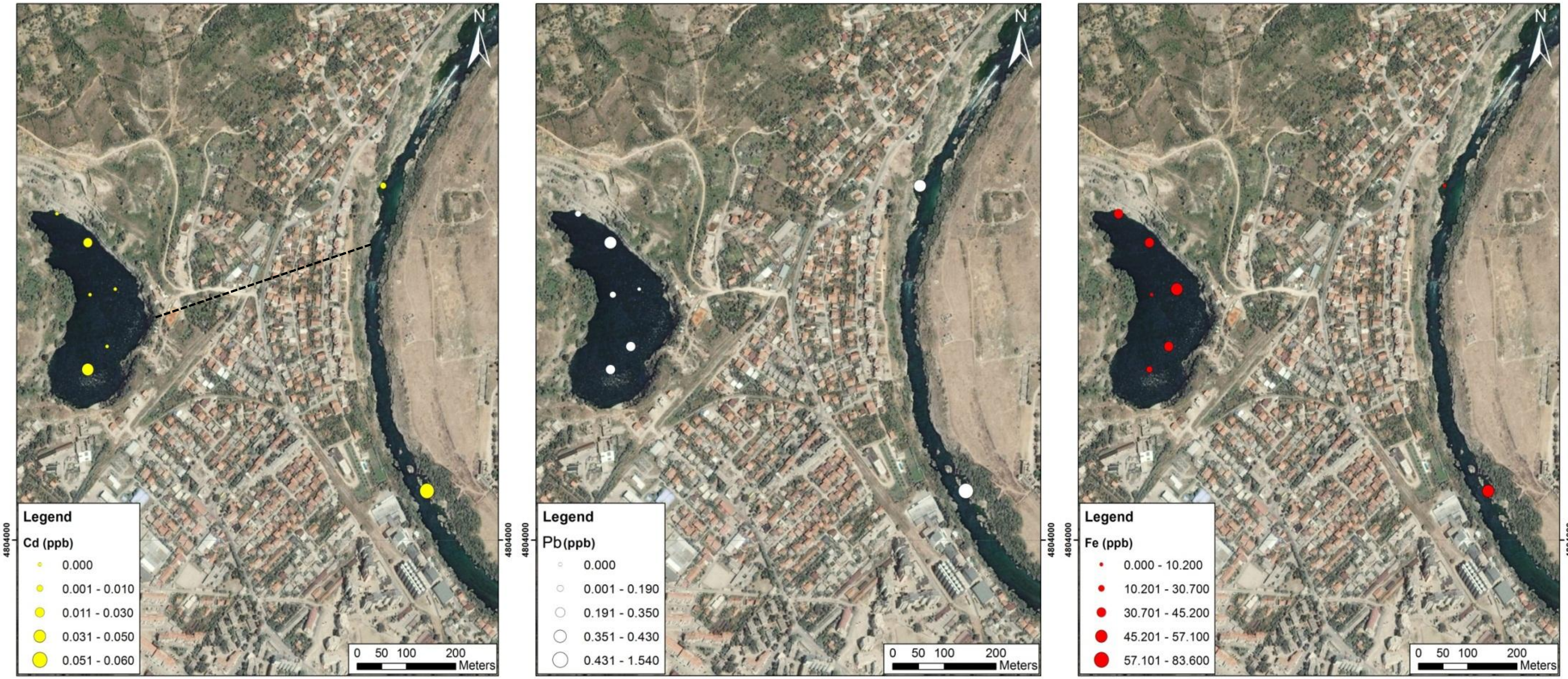


Figure 1 - Chlorophyll concentration from water chemistry data (all stations)



Note: lakewater is still while Neretva is fast-moving, bottom effects

Cadmium, Lead and Iron



Difficult to make firm impact calls based on too few samples, but Cd, Pb and Fe are all present in the lake, in greater concentrations than in Neretva.

Also, values for Cd, Pb and Fe are all elevated on the measurement point below the Neretva Tunnel

Observations

Air/Ground Observations:

- Increased quantities of sulfate minerals, possible alteration through uncontrolled burn
- Runoff of surface materials into water-bodies, point and non-point source pollution
- Considerable geotechnical hazard
- Illegal deposition and dumping of household and industrial waste
- Dispersal of alkaline dust (of unknown metal and radiological quantities)

All expected factors in improperly shut mining operation, clearly demonstrated by ImpactMin

Water Observations:

- Neretva river primarily affected by the urban environment and discharge from the urban area
- Difficult to discern all elements in fast-moving river
- Faint evidence of increased organic matter and heavy metals in the small number of samples taken – more detailed study of sediment recommended (20 years of accumulation).

Important Points

- First hyperspectral and first type of multi-sensor investigation in Western Balkans.
- Success in simultaneous or near-simultaneous acquisition of various datasets required to resolve complex regional problems
- First organized collection of empirical data in last 20 years (since 1992-95 conflict) in Mostar area
- Opened paths to new elements of collaboration and possibly new multidisciplinary projects (e.g. red muds)
- Formed baselines and standards for integration into GEOS as well as scientific contributions (WoS papers).

Conclusions

- Combined methods of remote sensing allow for the detection of evidence related to mineral extraction, processing and waste-product deposition in Mostar Valley
- Even though majority of imaged areas are inactive the data show and track changes to the environment in improperly shut and abandoned/unmaintained facilities
- The most evident problems are geotechnical in nature, illegal deposition of various types of waste, insufficient water treatment infrastructure and dust dispersal from waste-product facilities
- First real data after almost 20 year hiatus – good choice for this type of study because of complexity and interactions
- Excellent baseline for remediation, continued monitoring or other qualified projects in Horizon 2020