

Dennis Monbaliu, Sandrine Godefroid, Anatoly Peretyatko, Ludwig Triest, Nico Koedam
and Piet Boekaerts

Monitoring of vegetation stress and water quality of the Sonian Forest

CASI-TIR campaign 2003



Vrije Universiteit Brussel

- introduction
- objectives
- method
- results
- conclusions

Problem

Forest and ponds nearby urban areas need regular monitoring of their health status



Multiple measurements *in situ*



Intensive work & time consuming



Alternative: hyperspectral remote sensing

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Objectives

- Detect possible hyperspectral differences between unhealthy and healthy tree canopies
- Search for a potential correlation between the hyperspectral reflectance of ponds and their chemical, physical and biological characteristics

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CASI-TIR 2003 campaign

- June 16th 2003 between 11.40h and 12.30h
- Spatial resolution = 4,3m
- Spectral range: 405nm – 947nm (interval 5-6nm)
- 96 channels
- Region: Sonian Forest and Woluwe valley (N 50°47' and E 4°24')
- 6 flight tracks



True

R: 682nm

G: 546nm

B: 467nm

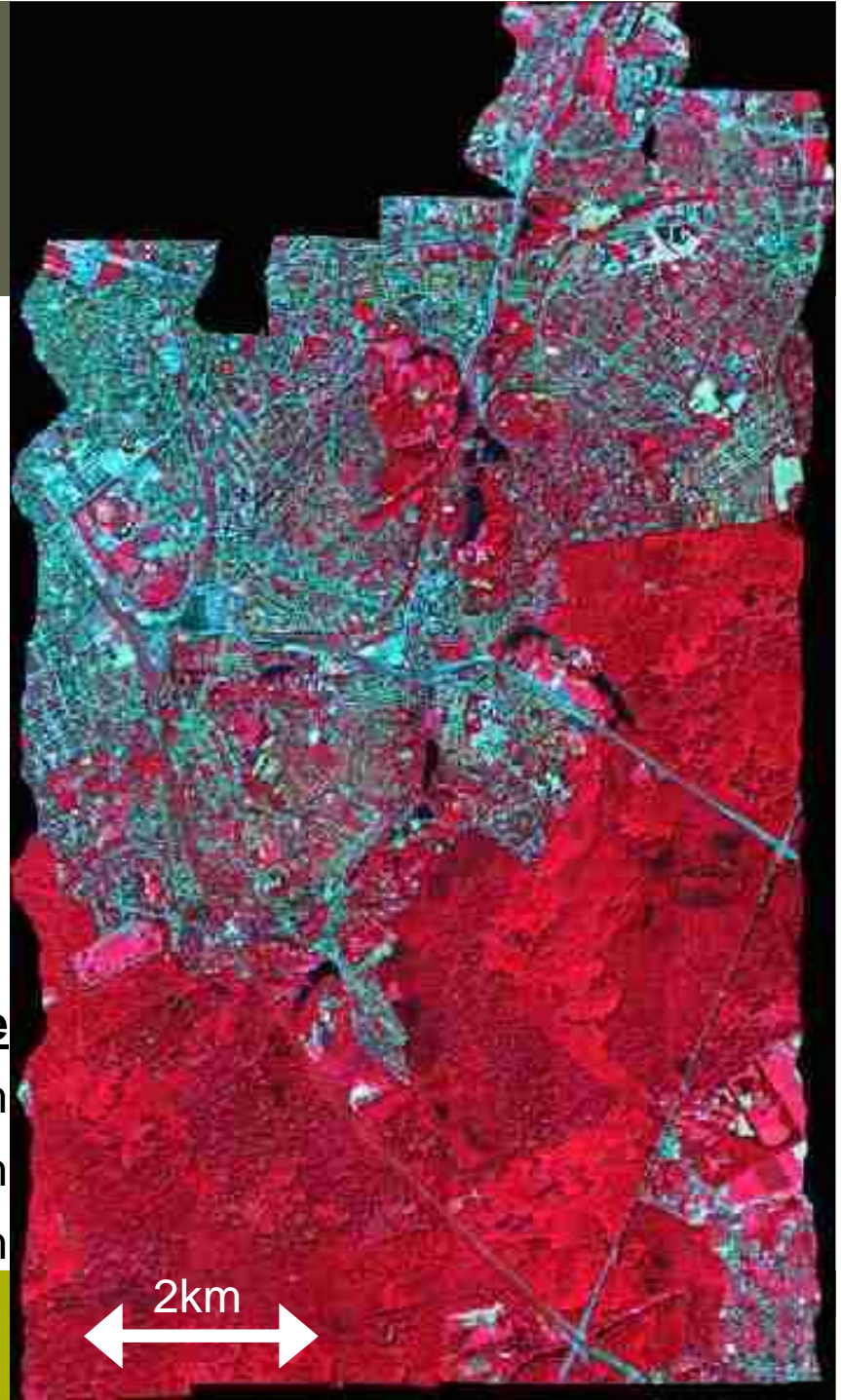
CASI

False

IR: 803nm

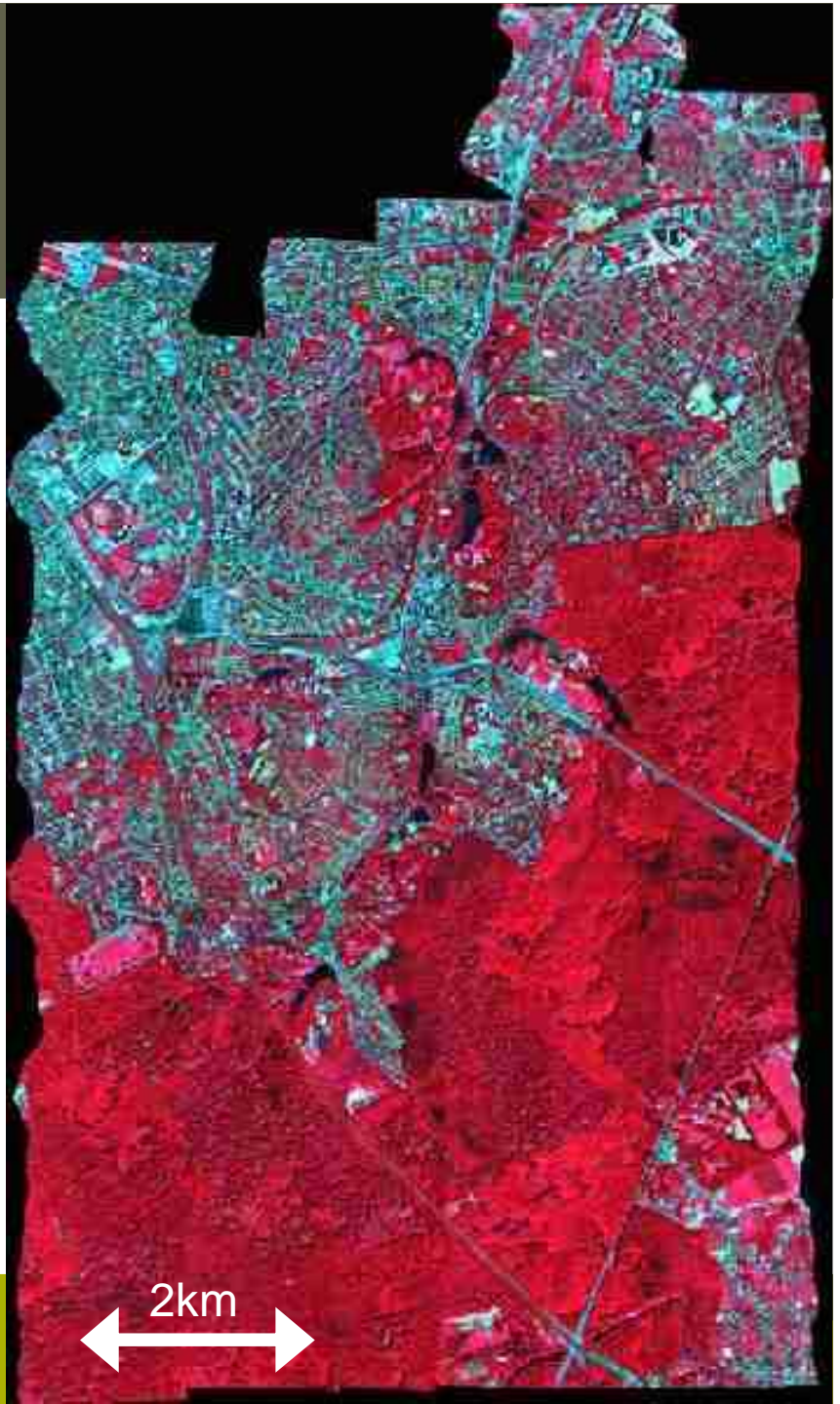
R: 682nm

G: 546nm





MOSAIC
View
angle
effect



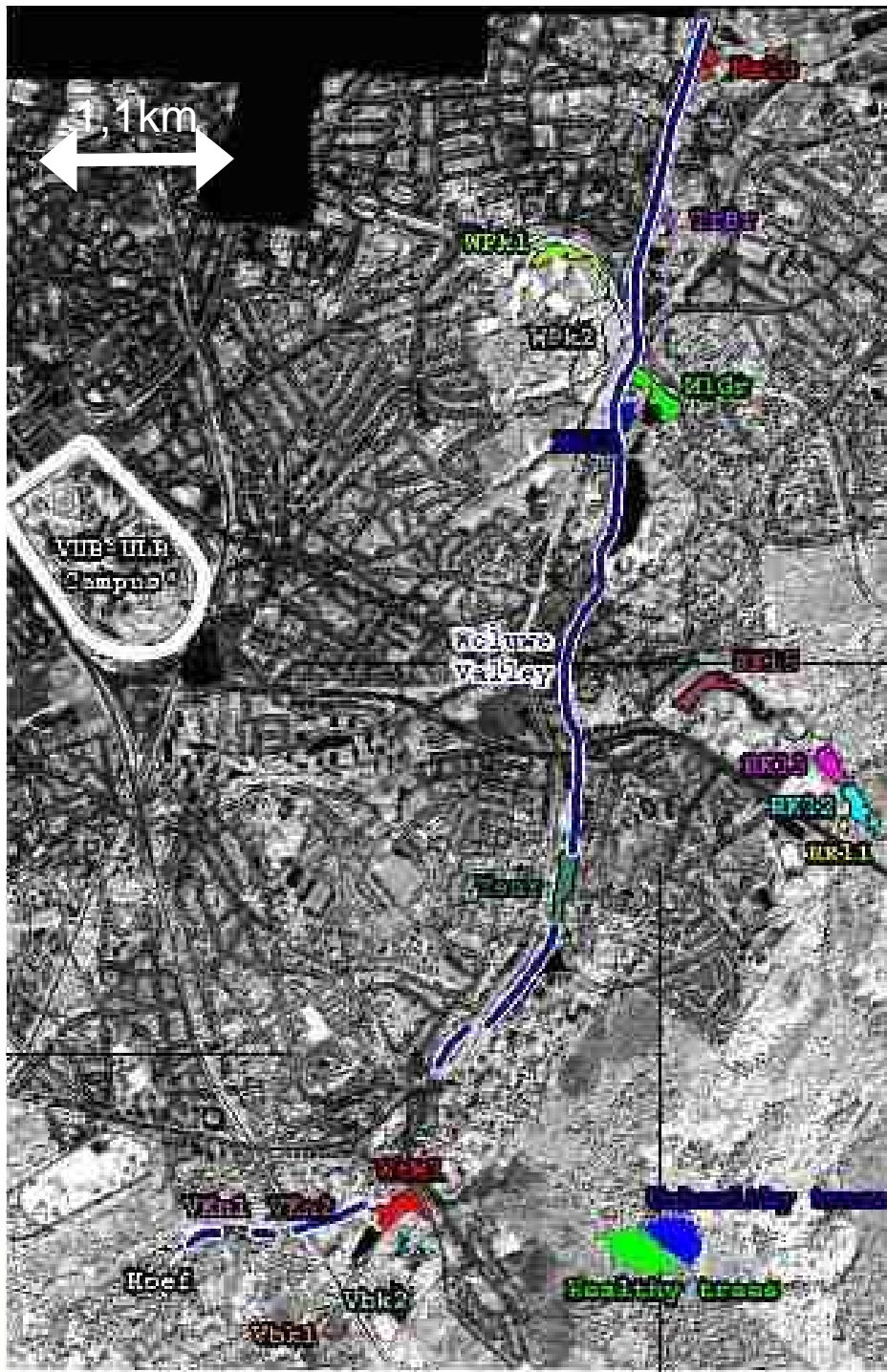
Regions of Interest

Forest

- 2 homogeneous areas with equal properties (age, soil, management, ...) except health status (according to BIM Brussels Institute for the Management of the Environment) inside Sonian Forest

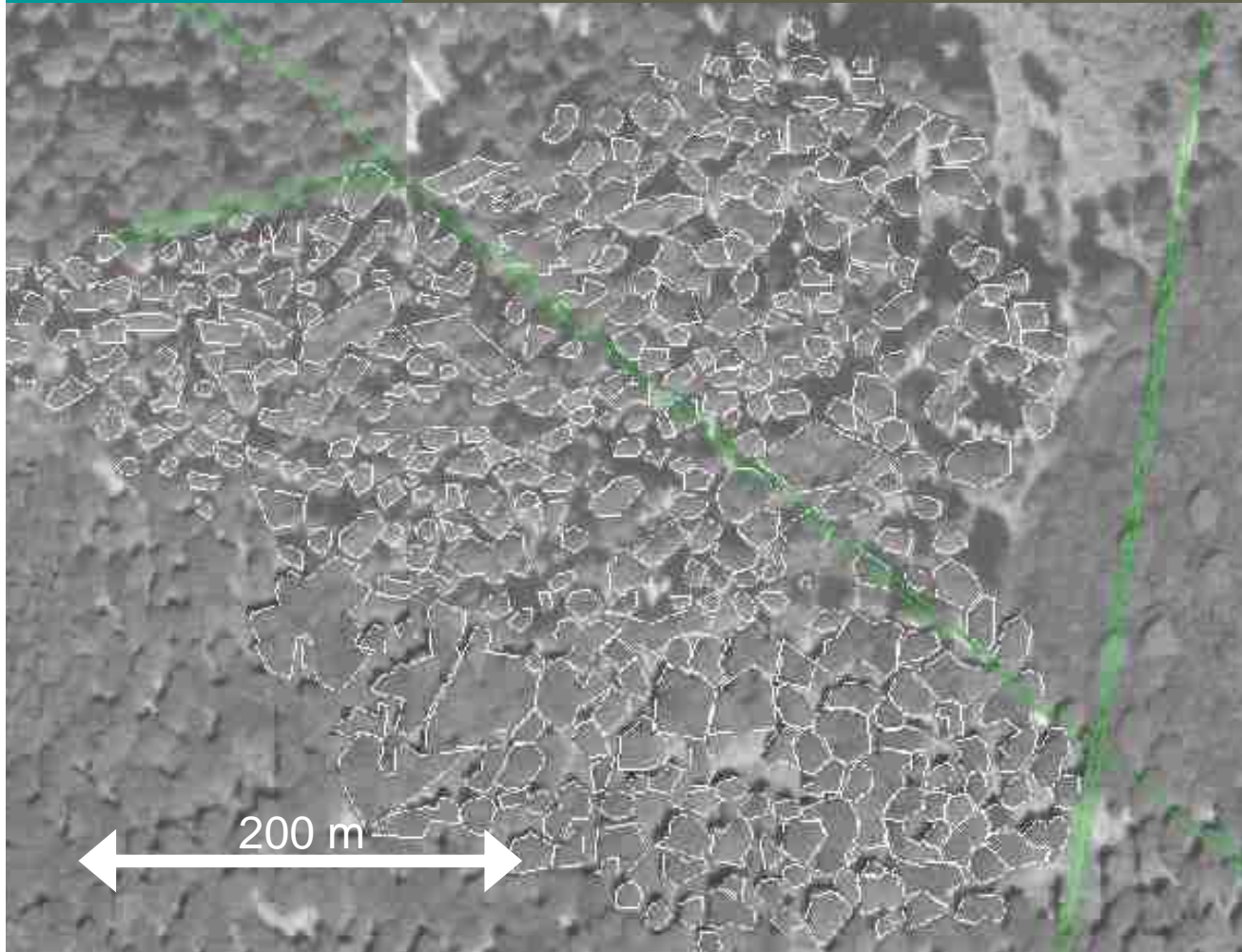
Ponds

- 17 ponds, monitored by the laboratory of General Botany and Nature Management (VUB, thanks to Anatoly Peretyatko) along the Woluwe valley



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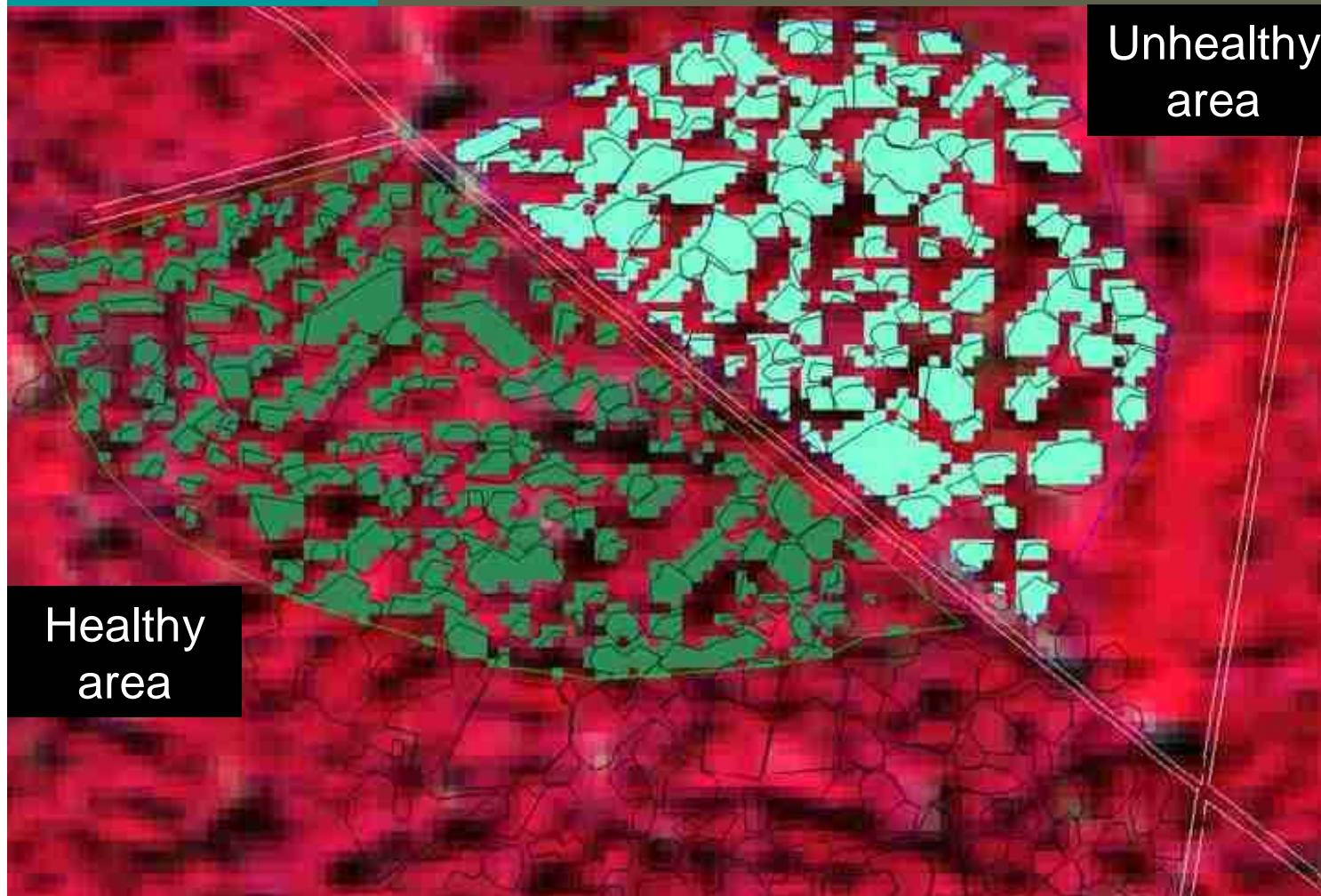
Tree canopies



- Digital orthophoto (1m)
- Polygons to mark tree canopies

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Tree canopies



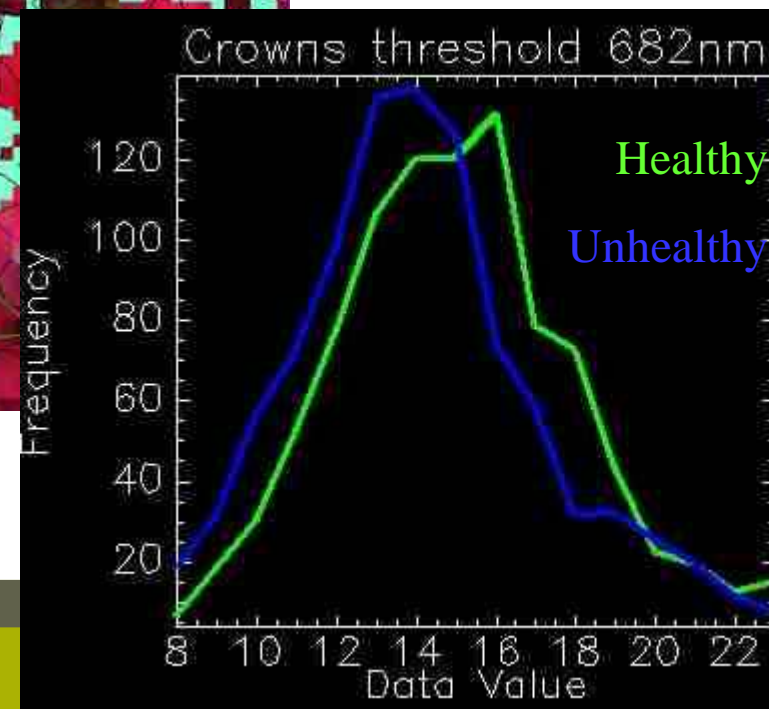
- Intersection of polygons with healthy and unhealthy area
- Healthy: 1089 pixels, 20136 m²
- Unhealthy: 1073 pixels, 19840 m²

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Band threshold



- Based on DN
- Homogenous pixels
- Between 800 & 900 pixels left



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14 selected wavelengths

| Wavelength (nm) | Band | Reason |
|-----------------|------|---|
| 405 | 1 | Lowest wavelength in spectral data |
| 428 | 5 | Absorption peak of chlorophyll a (430nm) |
| 450 | 9 | Absorption peak of carotene (451nm) and chlorophyll b (453nm) |
| 467 | 12 | Blue wavelength (468nm) |
| 546 | 26 | Green wavelength (548nm) |
| 642 | 43 | Absorption peak of chlorophyll b (642nm) |
| 660 | 46 | Absorption peak of chlorophyll a (662nm) |
| 682 | 50 | Red wavelength (680nm) |
| 700 | 53 | Systematic scale (according to Zhang et al., 2003) |
| 751 | 62 | |
| 803 | 71 | |
| 849 | 79 | |
| 901 | 88 | |
| 947 | 96 | Highest wavelength in spectral data |

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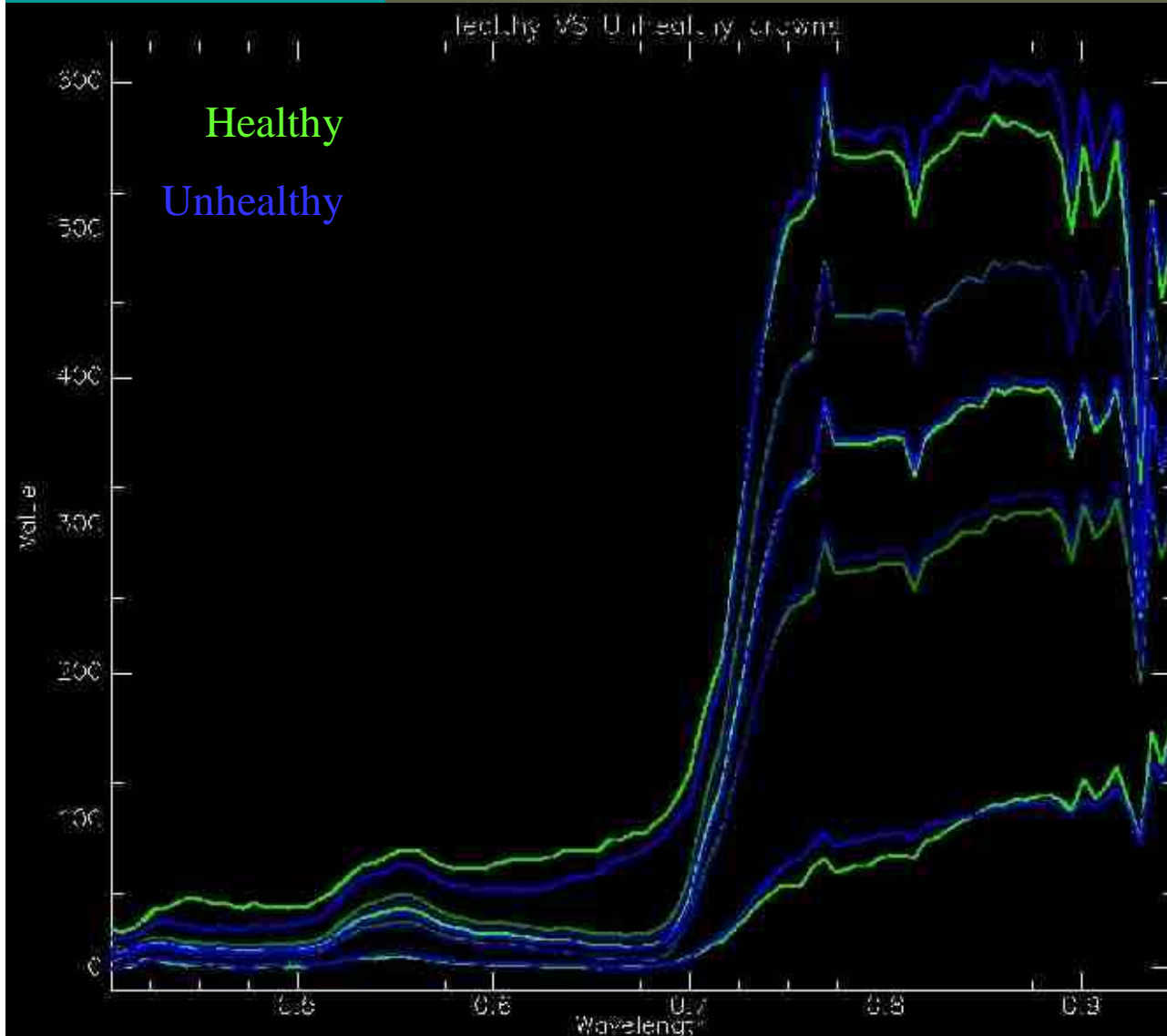
14 wavelengths Spectral indices

- Distributions of the intensity of the observed reflectance radiances of selected canopies were compared between healthy and unhealthy region
- Spectral indices (based on Sampson et al., 1998):

| | |
|---------------|-----------------------------------|
| 439nm / 688nm | 1 / 700nm |
| 694nm / 763nm | (734nm - 746nm) / (717nm - 728nm) |
| 751nm / 551nm | (529nm - 568nm) / (529nm - 568nm) |
| 751nm / 700nm | (803nm - 682nm) / (803nm + 682nm) |
- ENVI Statistics
- Wilcoxon Matched Pairs Test

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Healthy VS unhealthy



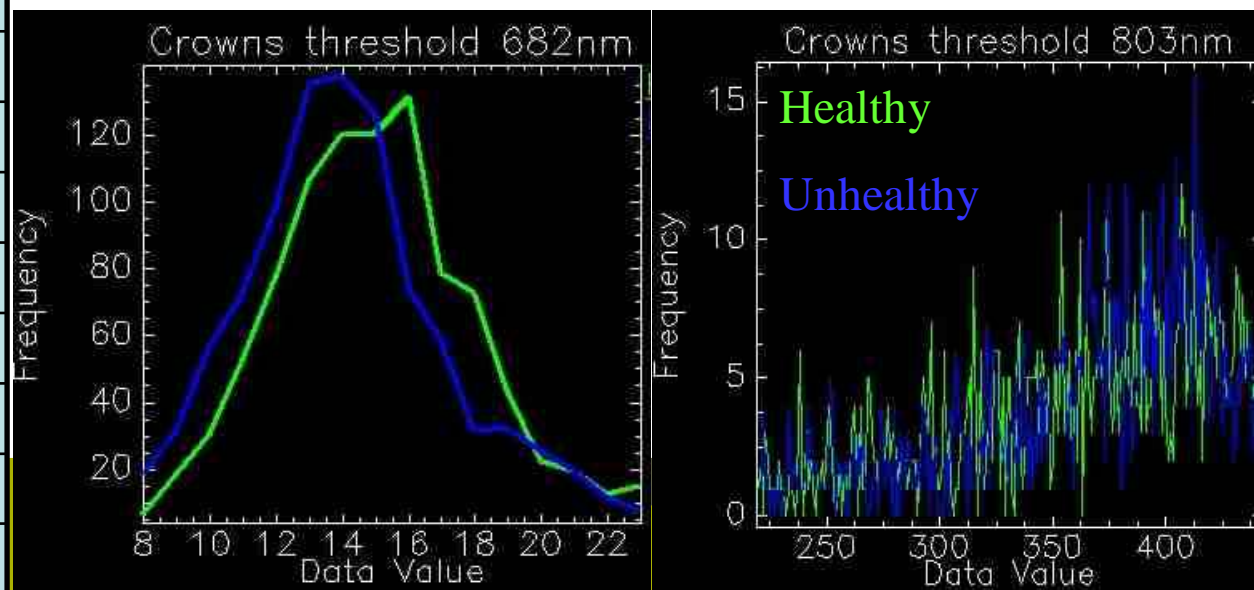
- Crowns
- Min, max, SD
- Visible range: higher reflectance values for healthy region
- NIR range: reversed tendency

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Healthy VS unhealthy

| Wavelength (nm) | N | p-level |
|-----------------|-----|----------|
| 405 | 8 | 0.865772 |
| 428 | 9 | 0.213525 |
| 450 | 10 | 0.646462 |
| 467 | 8 | 0.779435 |
| 546 | 21 | 0.348011 |
| 642 | 15 | 0.842430 |
| 660 | 15 | 0.776425 |
| 682 | 16 | 0.513656 |
| 700 | 34 | 0.211027 |
| 751 | 219 | 0.496066 |
| 803 | 225 | 0.841518 |
| 849 | 213 | 0.441368 |
| 901 | 196 | 0.276777 |
| 947 | 147 | 0.117583 |

- No significant difference in reflectance between the whole regions ($0,16 < p < 0,98$)
- No significant difference in reflectance between tree canopies
- Small differences in histograms



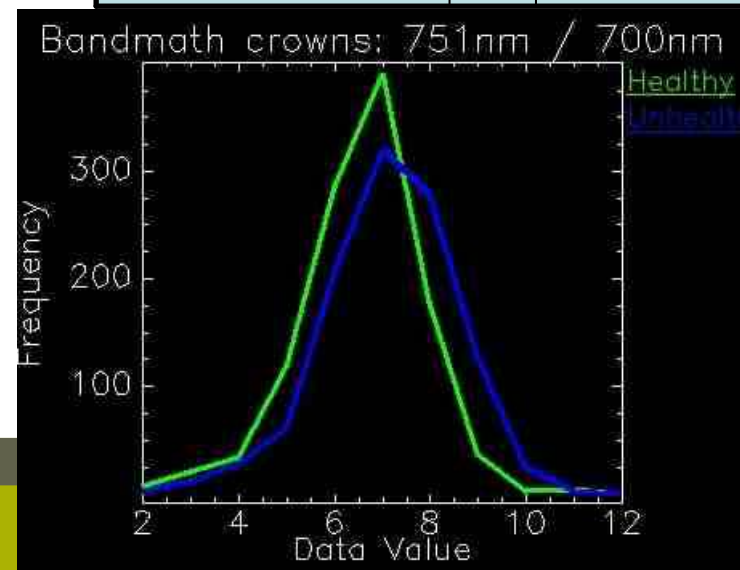
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Spectral indices



- No significant difference
- Small differences in histograms

| Spectral index | N | p-level |
|----------------|----|----------|
| 439nm / 688nm | 3 | 0.592980 |
| 751nm / 551nm | 10 | 0.721277 |
| 751nm / 700nm | 12 | 0.656642 |



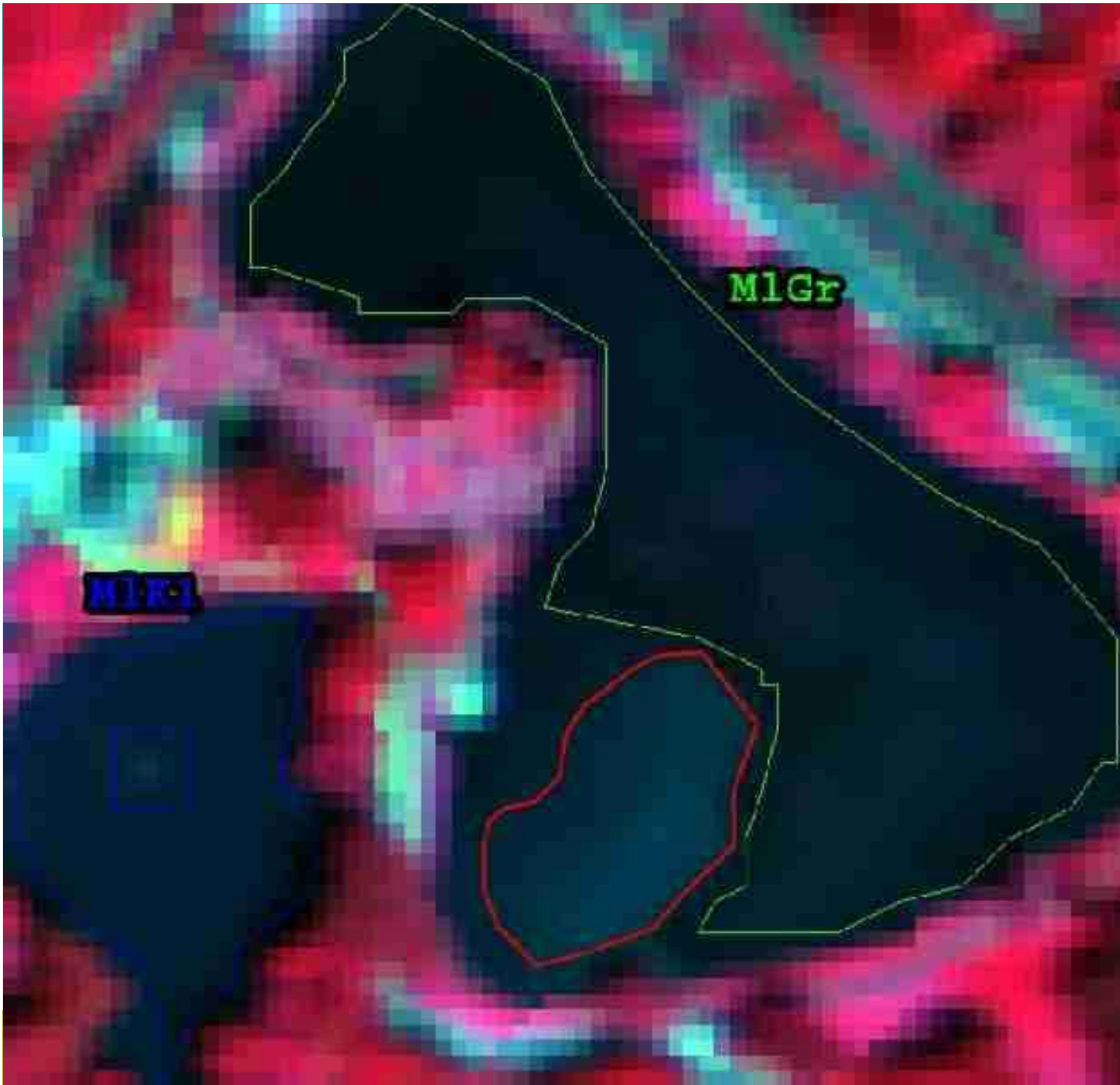
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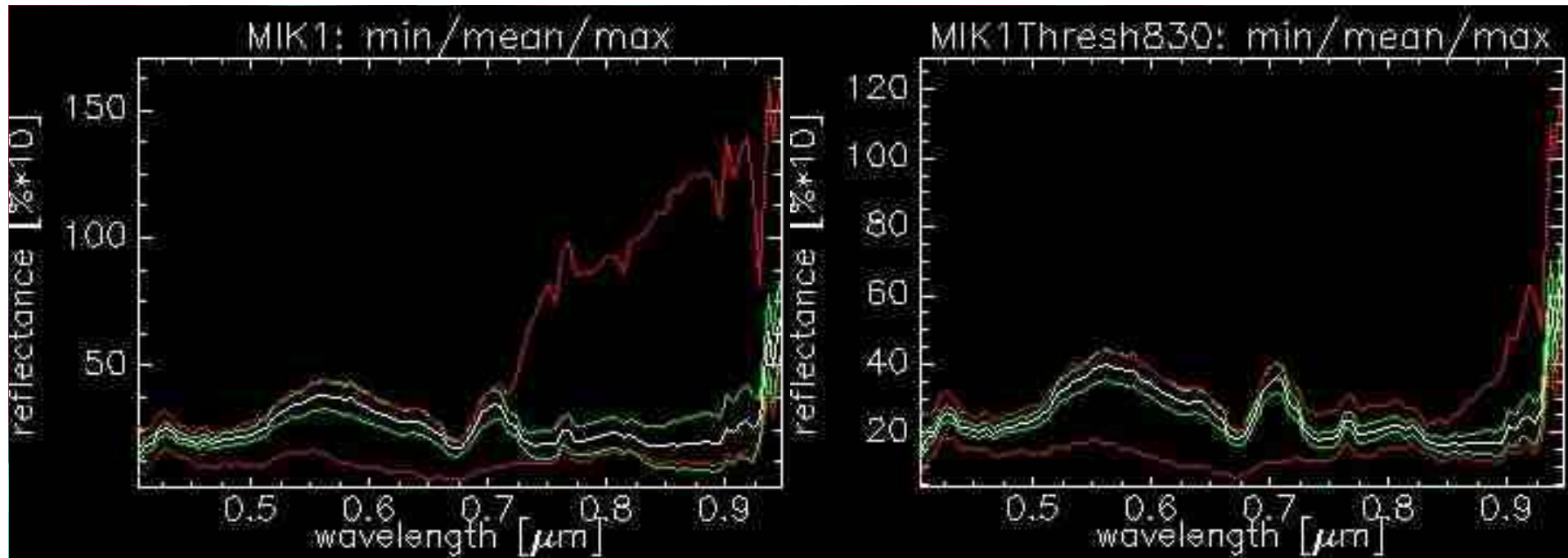
17 Ponds

- Monitored during and 1 day after flight campaign
- Phytoplankton abundance and diversity
- Physical characteristics (conductivity, depth (secchi), temperature)
- Chemical variables (NO_n^- , NH_4^+ , TP, SRP, O_2 , Si, Cl^-)

17 Ponds

- Bordering of ponds (ROI)
- Removal of heterogeneous areas (bottom of ponds, macrophytes)
- Between 35 and 1165 pixels (650m² and 21540m²)





- Threshold on wavelength 830nm

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19 wavelengths Correlation

- Correlation between mean spectral reflectance of 19 wavelengths and the biological, physical and chemical properties of the 17 ponds
- Same wavelengths as for the tree canopies
- 5 additional bands (based on photosynthetic pigments of phytoplankton)
- ENVI Statistics
- Spearman Rank Order Correlation

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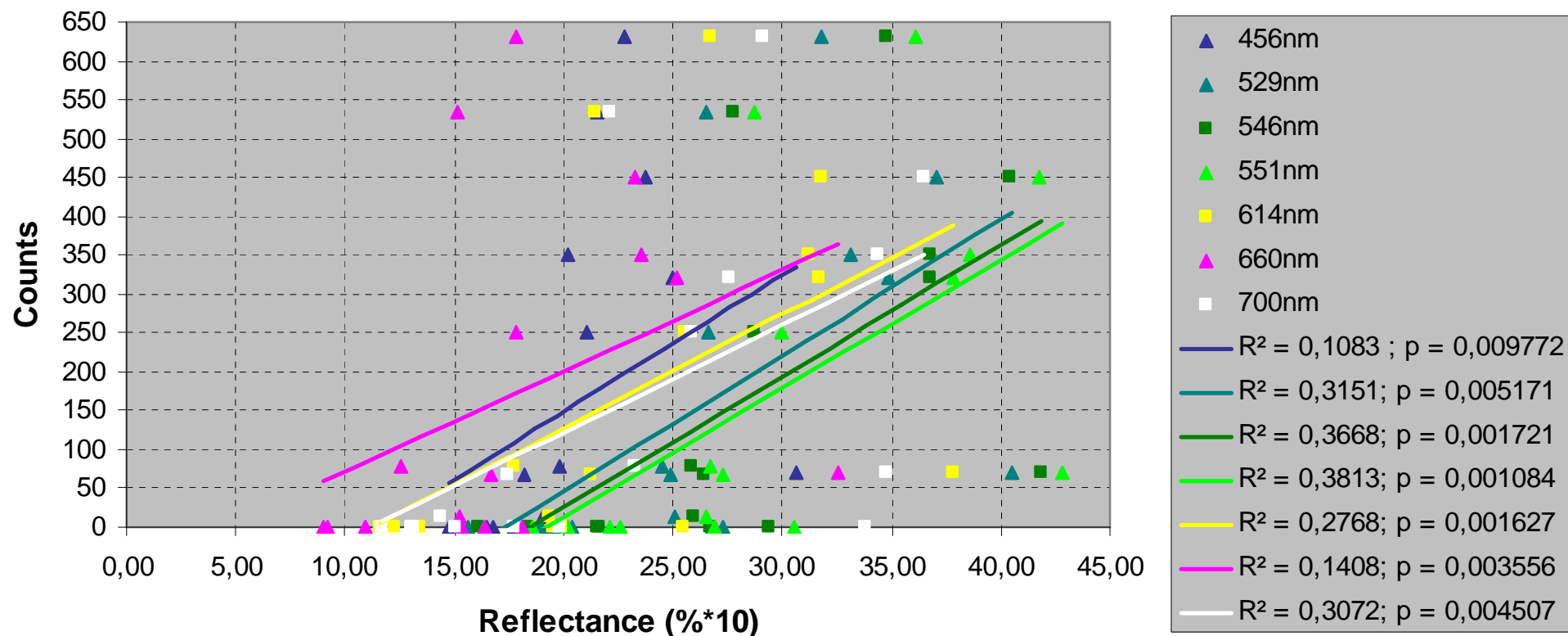
Phytoplankton

- **Bacillariophyta, Chlorophyta, Cyanobacteria and Xanthophyta** were significantly correlated with the reflection intensities of 12 wavelengths (**428nm – 700nm**)

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Phytoplankton

Division of Xanthophyta per site VS mean reflectance



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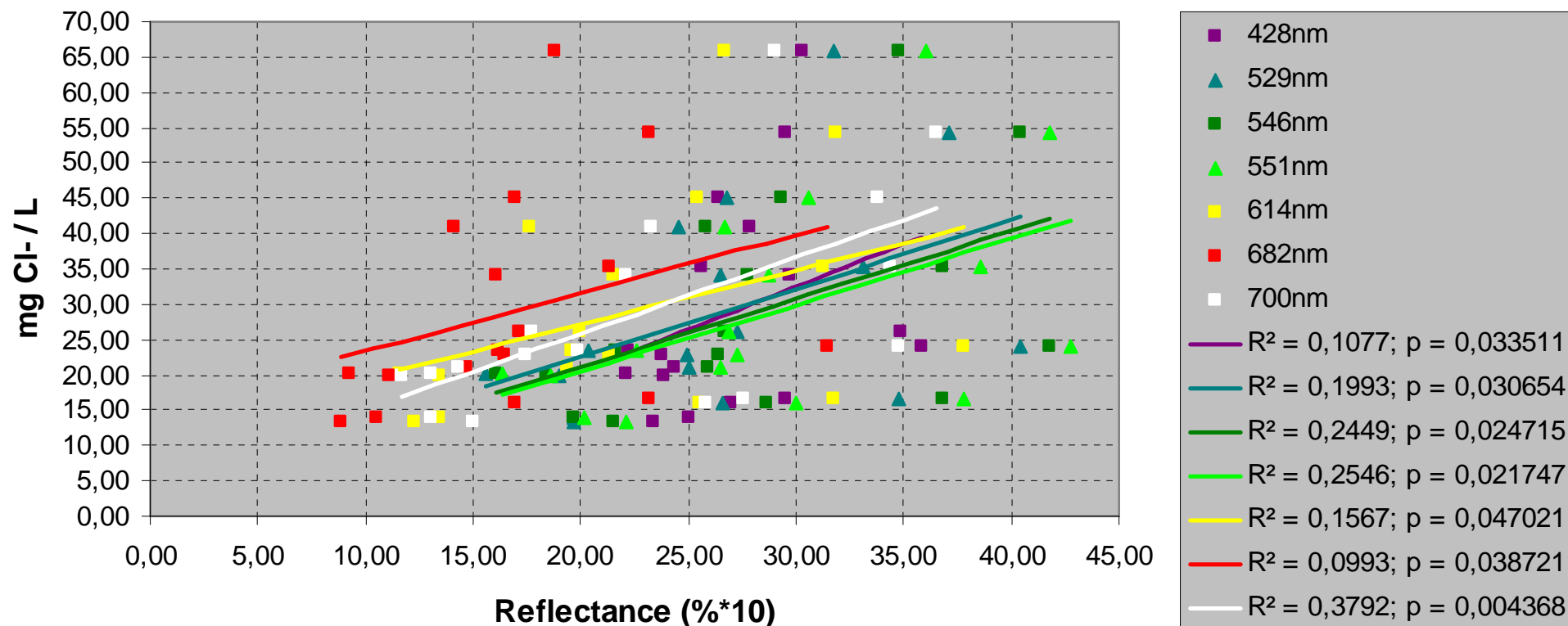
Physical & chemical

- 5 environmental variables showed a significant correlation with the reflection intensities
 - amount of chlorine (8 wavelengths)
 - total amount of phosphorus (5 wavelengths)
 - % saturation of O₂ (6 wavelengths)
 - temperature (6 wavelengths)
 - depth of secchi disc (2 wavelengths)

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Physical & chemical

mg Cl⁻ / L VS mean reflectance



- No significant difference could be detected between healthy and unhealthy forest stands
 - Tree level
 - Other vegetation indices
- Promising results in the relation between hyperspectral data and environmental properties of ponds