HYPERPEACH

Modeling biochemical processes in orchards at leaf- and canopy-level using hyperspectral data

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Overview

Objectives

Methodology

- Plot preparation
- Field and airborne campaigns
- Generation of vegetation indices
- C_{ab} retrieval

Results

- Vegetation indices
- General results (biochemical)
- C_{ab} retrieval

Conclusions

Objectives

Objectives

Monitoring crop status via hyperspectral remote sensing

Are we able to detect iron stress in orchards via hyperspectral remote sensing?

Generate novel & robust indices

Test classical vegetation indices and generate novel, robust indices enabling effective detection and quantification of iron deficiency in the peach orchard (leaf, canopy & airborne level)

- Band reduction techniques
- Standardized difference vegetation indices (SDVI)

Chlorophyll a+b retrieval

Can we quantitatively estimate chlorophyll concentration from hyperspectral remote sensing?

Plot preparation

Methodology

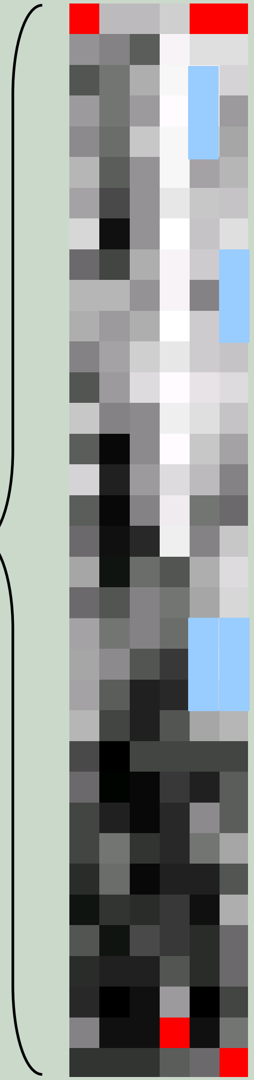
- Research plot in Zaragoza (Spain)
- Orchard: 205 peach (*Prunus persica L.*) trees

- Stress:
  - Iron Chlorosis induced in rows 1 and 2 (48 trees)
  - Iron chelate treatments (Sequestrene): 0, 60, 90, 120 g/tree

Peach orchard in Zaragoza

Methodology

35 x 6 rows



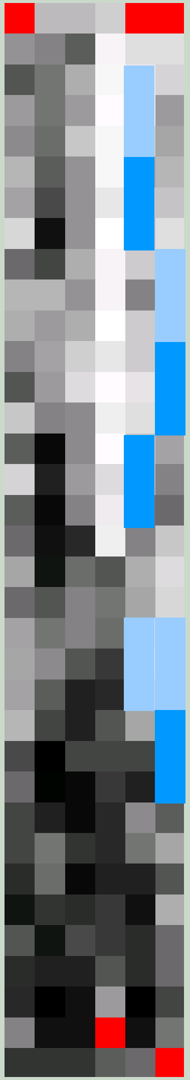
0 g/tree

■ missing tree

Peach orchard in Zaragoza

Methodology

35 x 6 rows

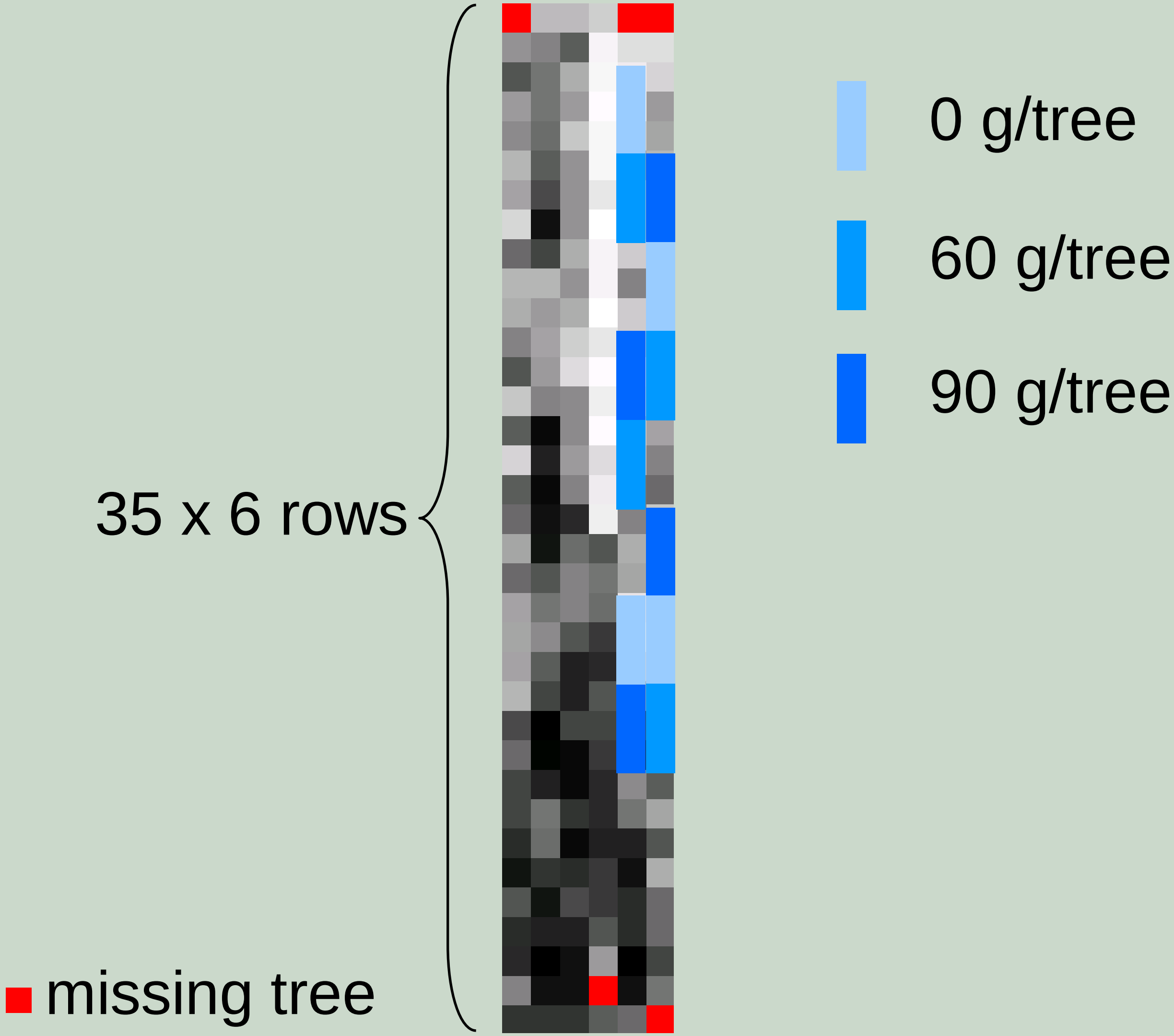


0 g/tree

60 g/tree

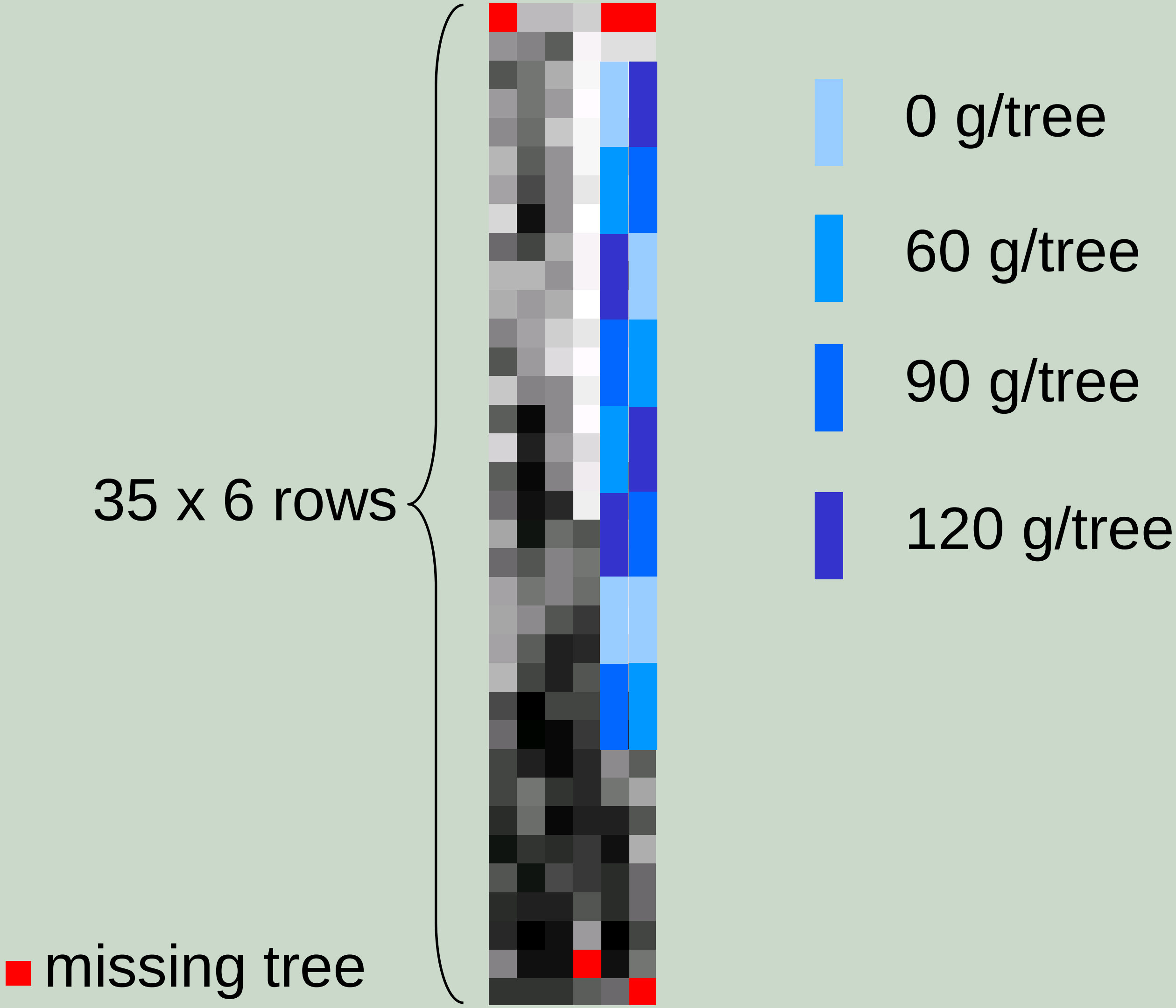
■ missing tree

Methodology



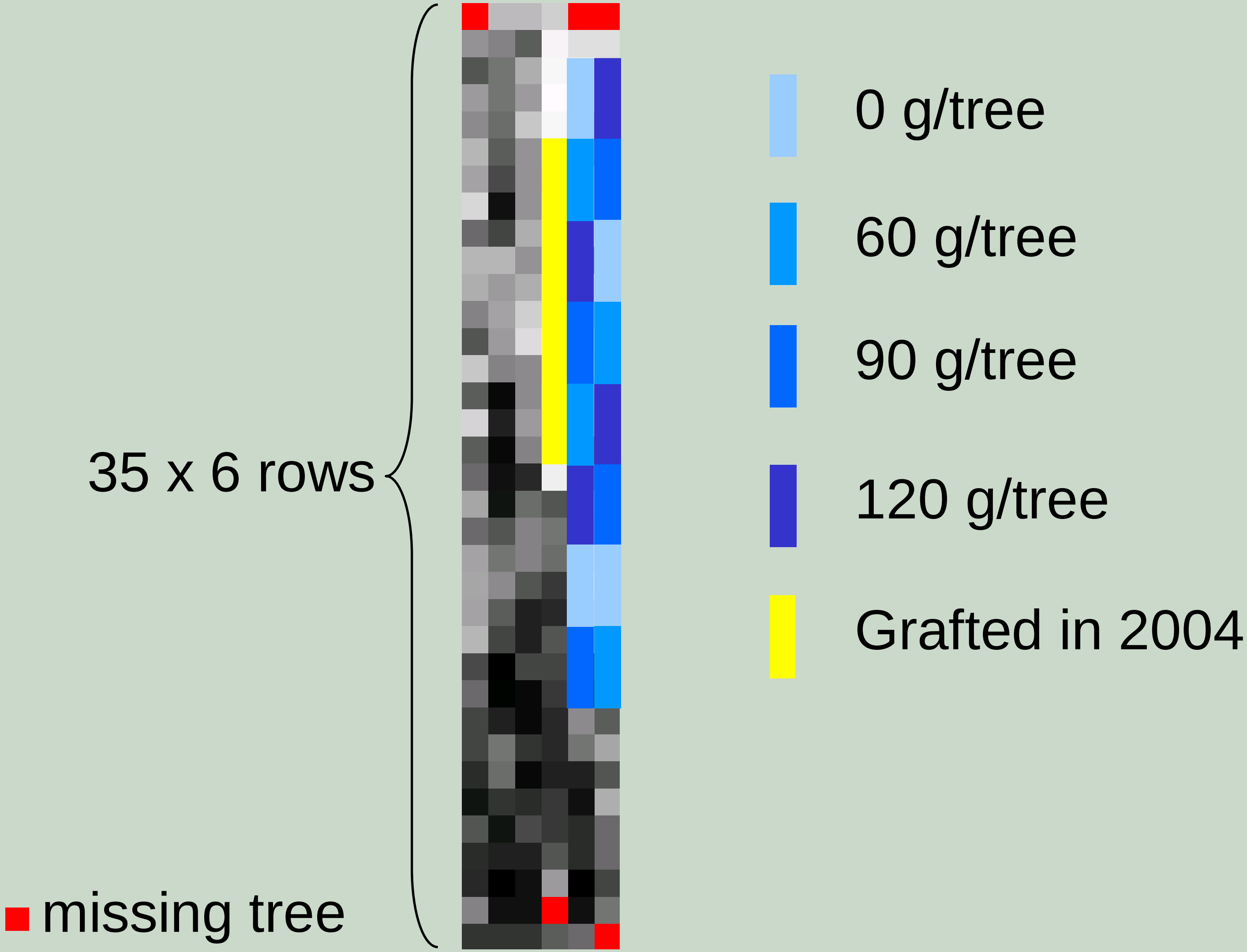
Peach orchard in Zaragoza

Methodology



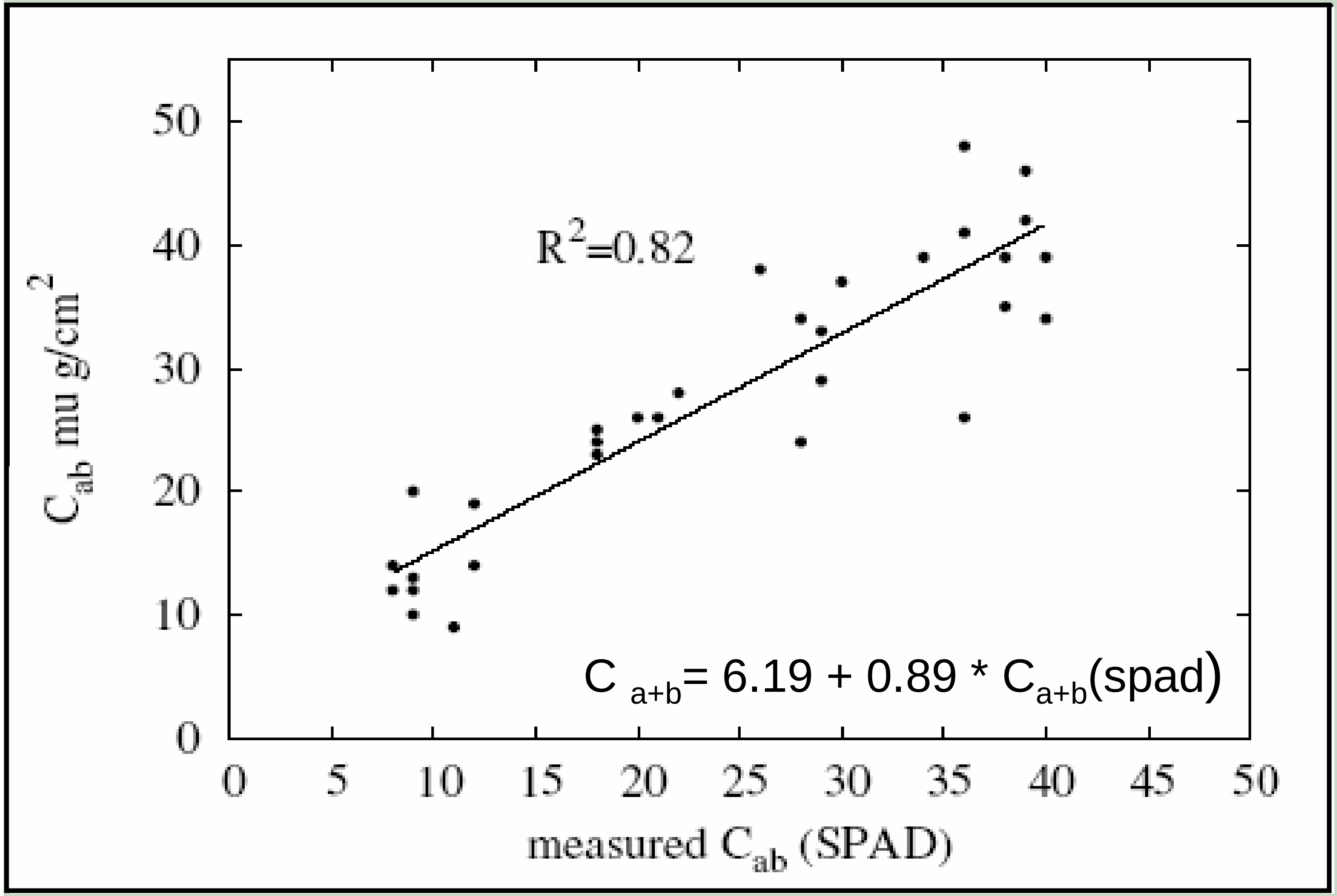
Peach orchard in Zaragoza

Methodology



Field Campaign

Methodology



Field Campaign

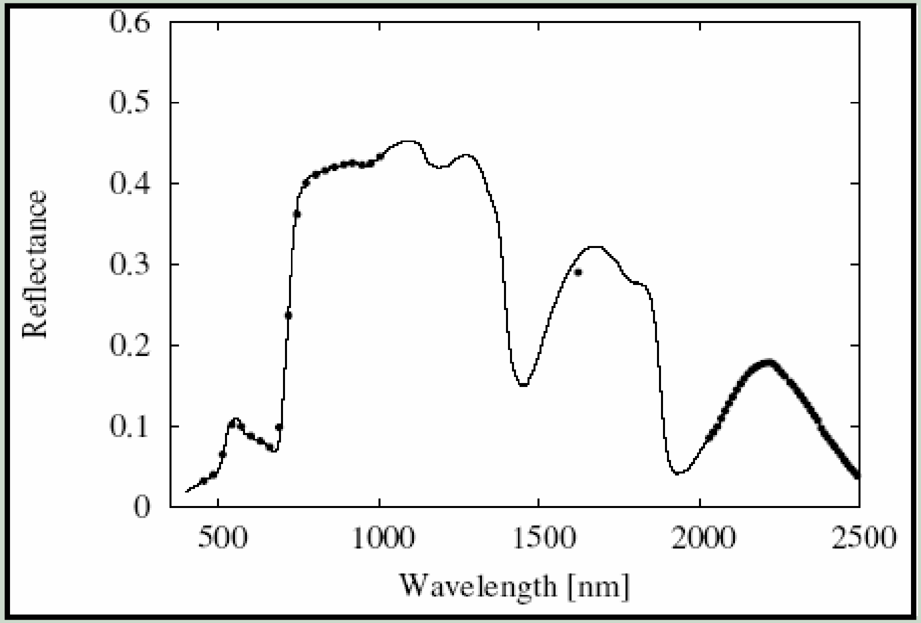
Methodology

Canopy level

- Canopy reflectance of 72 trees (ASD 25°FOV)
- LAI measurements (LAI-2000)

Methodology

SensyTech AHS Hyperspectral sensor (INTA, Spain)



Spectral bands:

VIS+NIR 430 - 1030 nm: 20 bands ($\Delta\lambda$ = 30 nm)

SWIR 1 (1550 - 1750 nm): 1 band ($\Delta\lambda$ = 200 nm)

SWIR 2 (1994 - 2540 nm): 42 bands ($\Delta\lambda$ = 13 nm)

Hyperspectral image

Methodology

Spatial resolution: 2.5m
Crown diameter: 2.5m

Tree identification

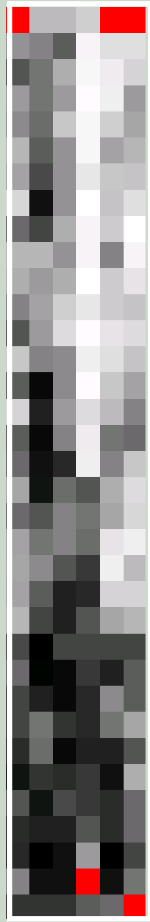
Methodology

672 pixels
(16/5 pixels/tree)

5x5
Subsampling
(nearest
neighbor)

16800 pixels
(80 pixels/tree)

Median
value



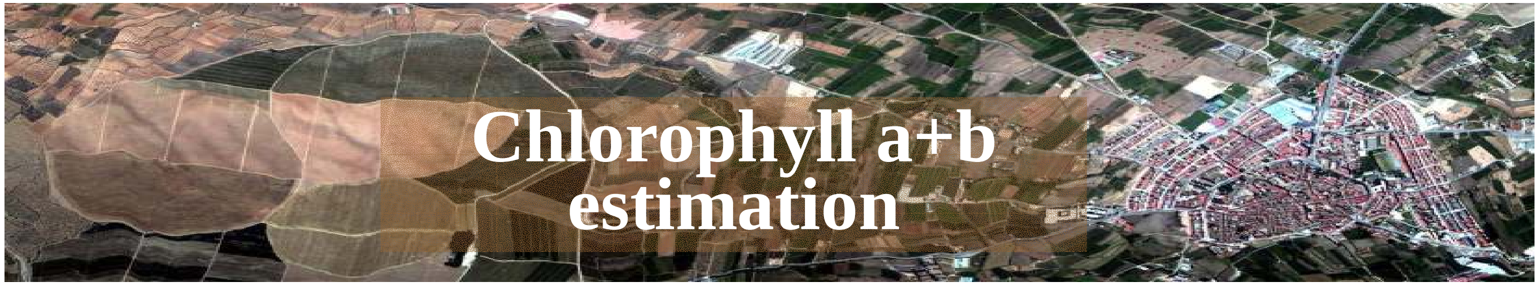
210 pixels
(1 pixel/tree)

Vegetation indices

Methodology

Problem	High dimensionality of the hyperspectral dataset (“oversampled” dataset: 350-2500 nm)
Solution	Index development to reduce complexity and easily distinguish between treatments

This research
Identification of hyperspectral indices to detect differences between reflectance spectra of healthy and iron deficient trees (leaf, canopy and airborne level)



Chlorophyll a+b estimation

Methodology

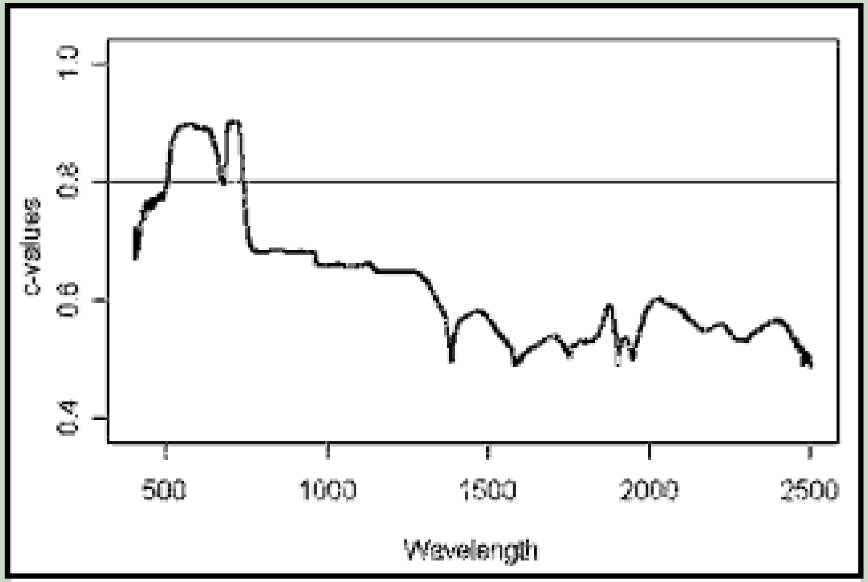
Radiative transfer model
Model inversion (PROSPECT + ACRM)

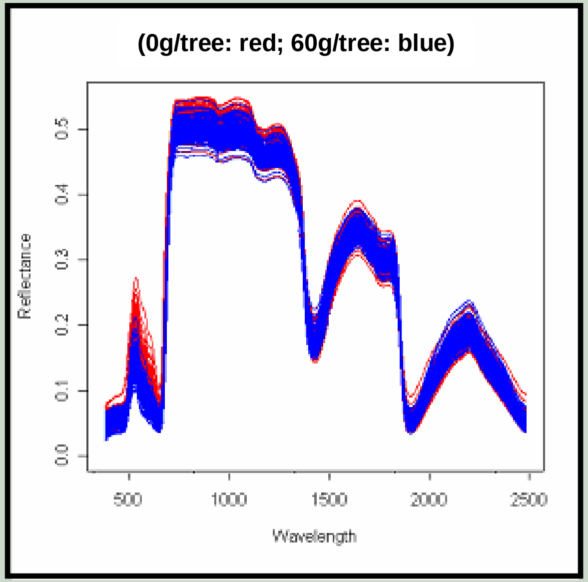
Increase complexity level:
Leaf level (*in situ* measurements)
Canopy level (*in situ* measurements)
Airborne level (atmospherically corrected)

Band reduction techniques

Results VI

Band selection using logistic regression



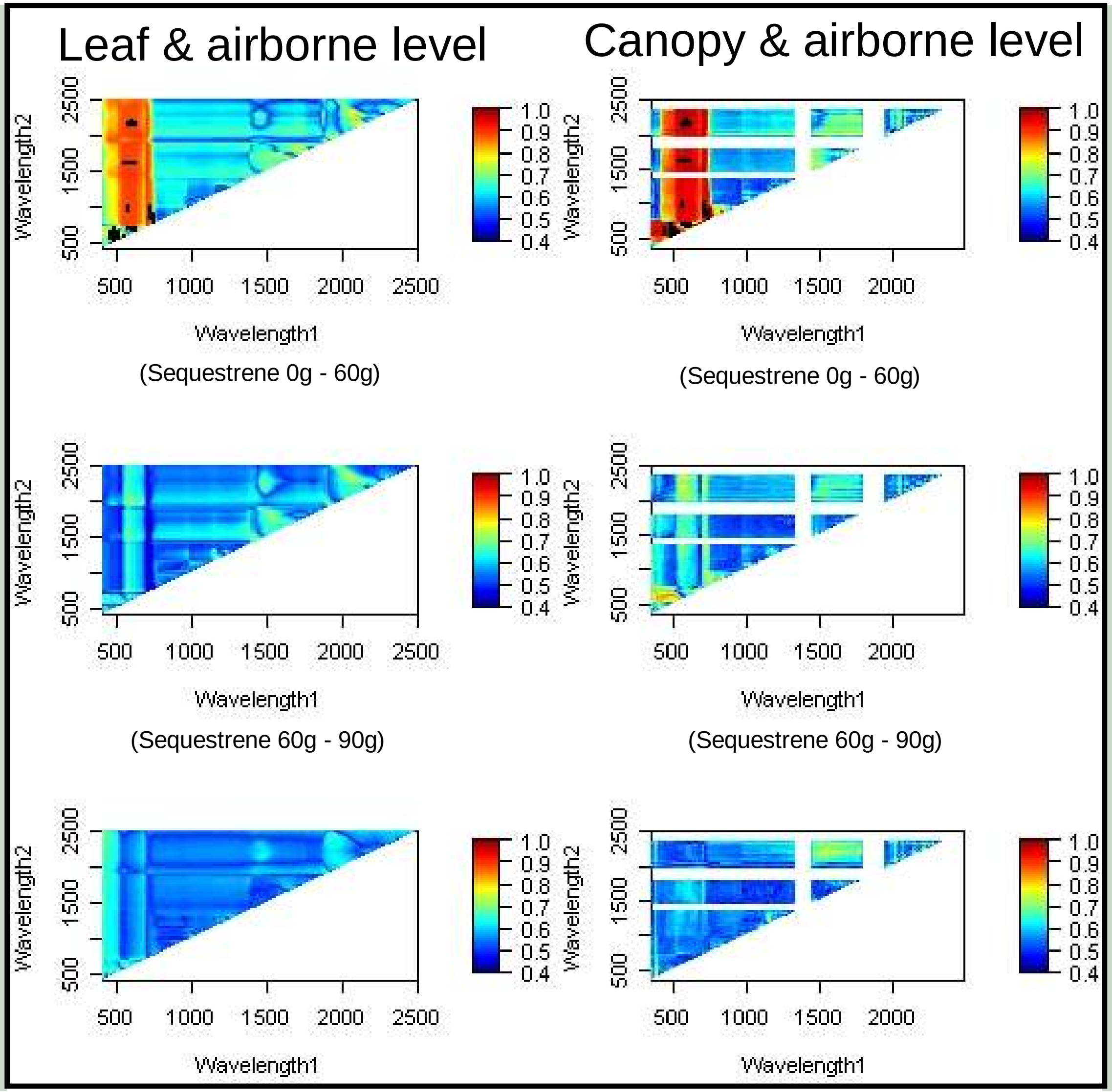


Sequestrene application 0g/tree ⟷ 60g/tree

Narrow-waveband ratioing involving all possible 2-band combinations

$$SDVI = \frac{wavelength\ 2 - wavelength\ 1}{wavelength\ 2 + wavelength\ 1}$$

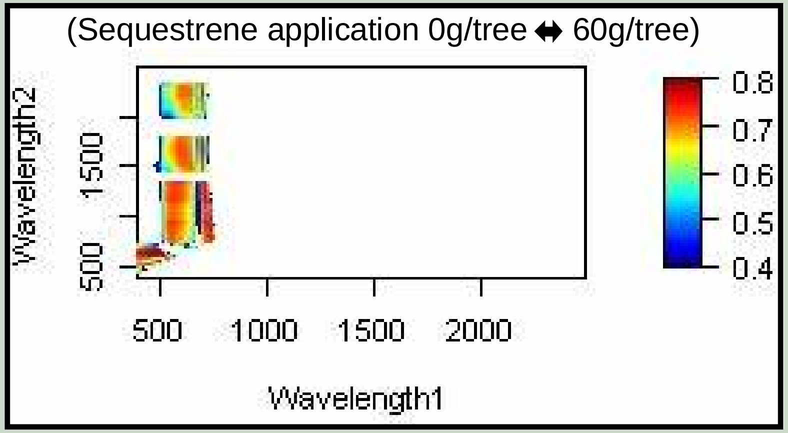
Results SDVI



Selected SDVI ~ Chl

Results SDVI

Linear relation SDVI and Chl



Most discriminative SDVI closely related to chlorophyll concentration

Selected SDVI ~ Chl

Some General Results

Fluorescence

Linear and positive relationship between Fs and leaf chlorophyll concentration found

Biochemical parameters

Fe-deficient leaves:

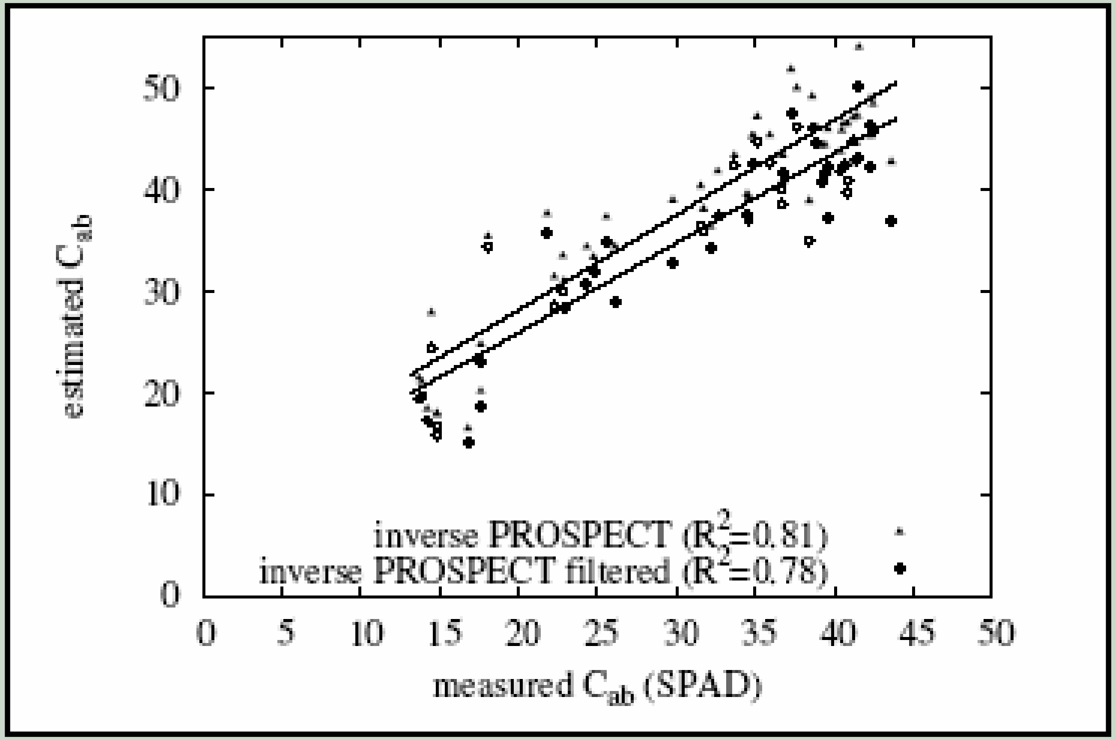
- dry mass per leaf area unit ↘
- relative water content ↗
- [chlorophylls] & [carotenoids] ↘

Peach yield

Lower peach yield in trees that did not receive iron, compared to those treated with different amounts of iron

Model Inversion (leaf level)

Results Cab retrieval



Model Inversion (canopy level)

Results Cab retrieval

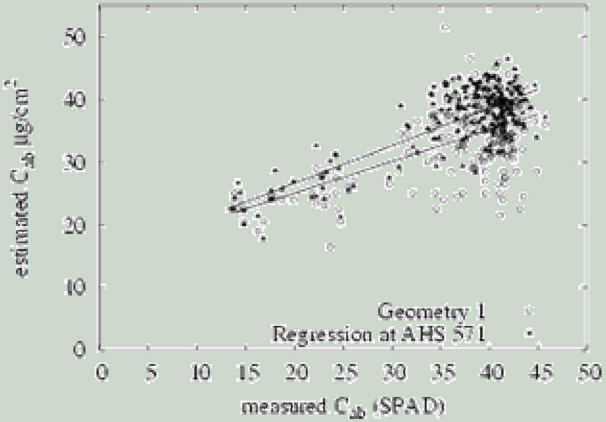
Proposed methodolgy:

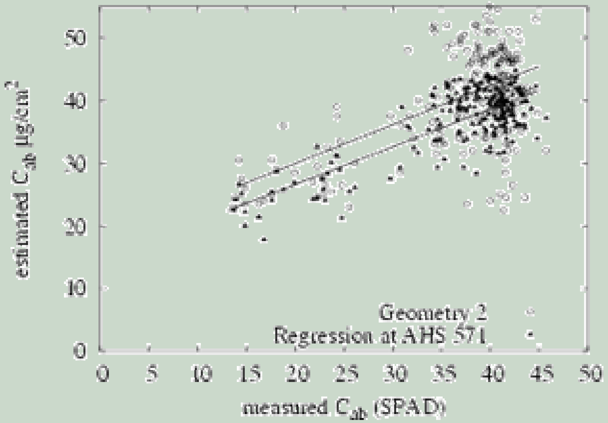
- Inversion of PROSPECT+ACRM
- Improvements for inversion proposed:
  - Adapted simulated annealing [Ingber, 1993]
  - Filtering of modeled spectra according to AHS sensor
  - Multi-angular information

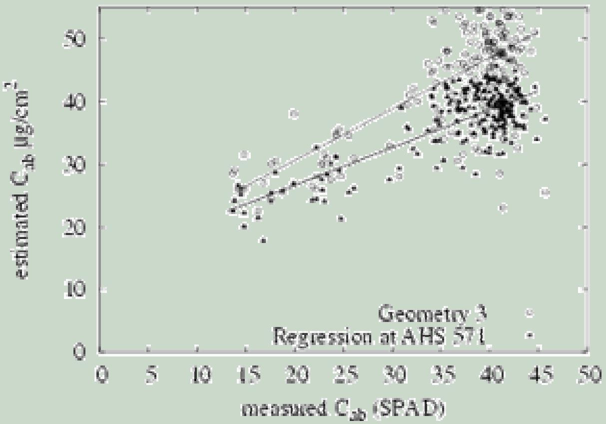
(Ingber 1993, http://ideas.repec.org/p/lei/ingber/93asa.html)

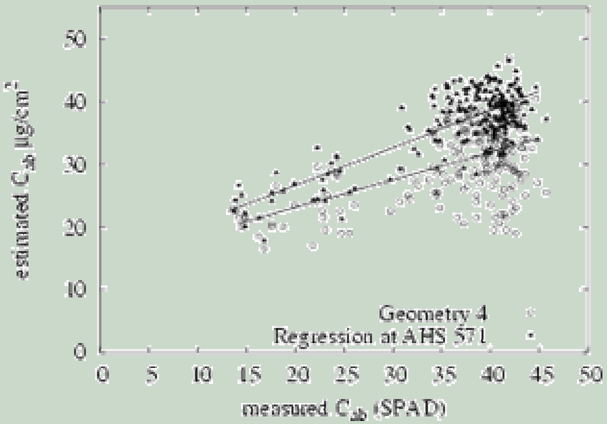
Results using single observation

Results Cab retrieval



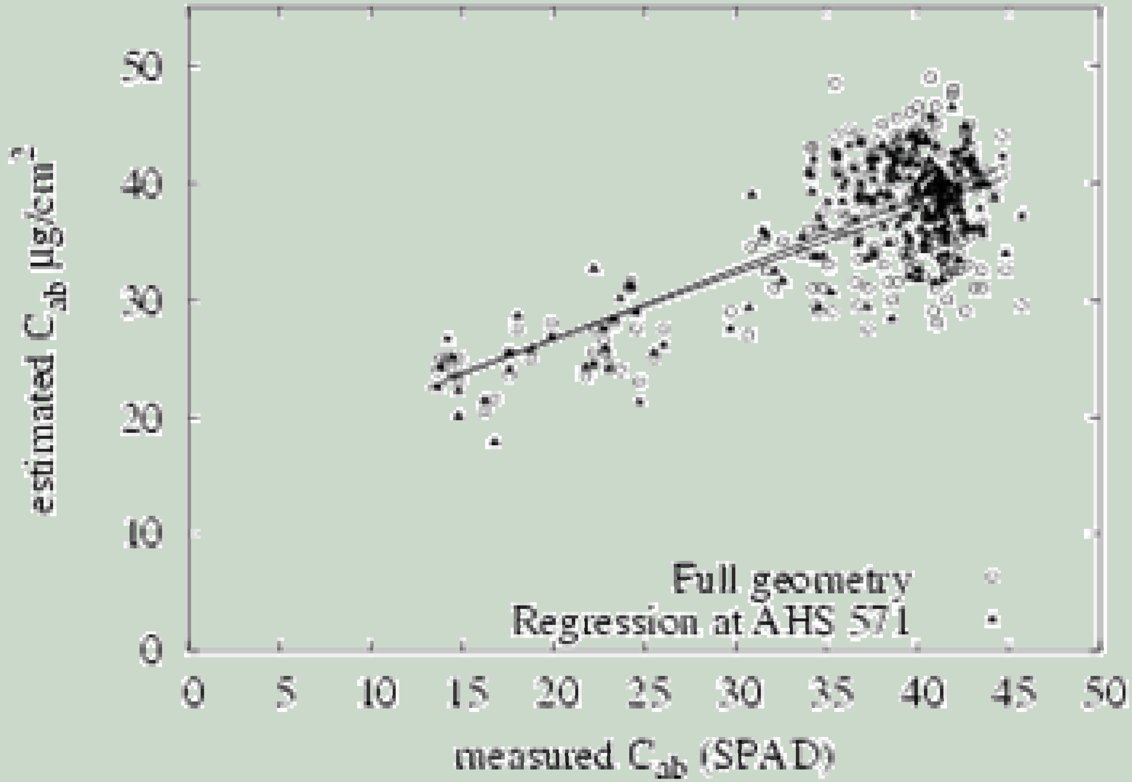






Results using all observations

Results Cab retrieval



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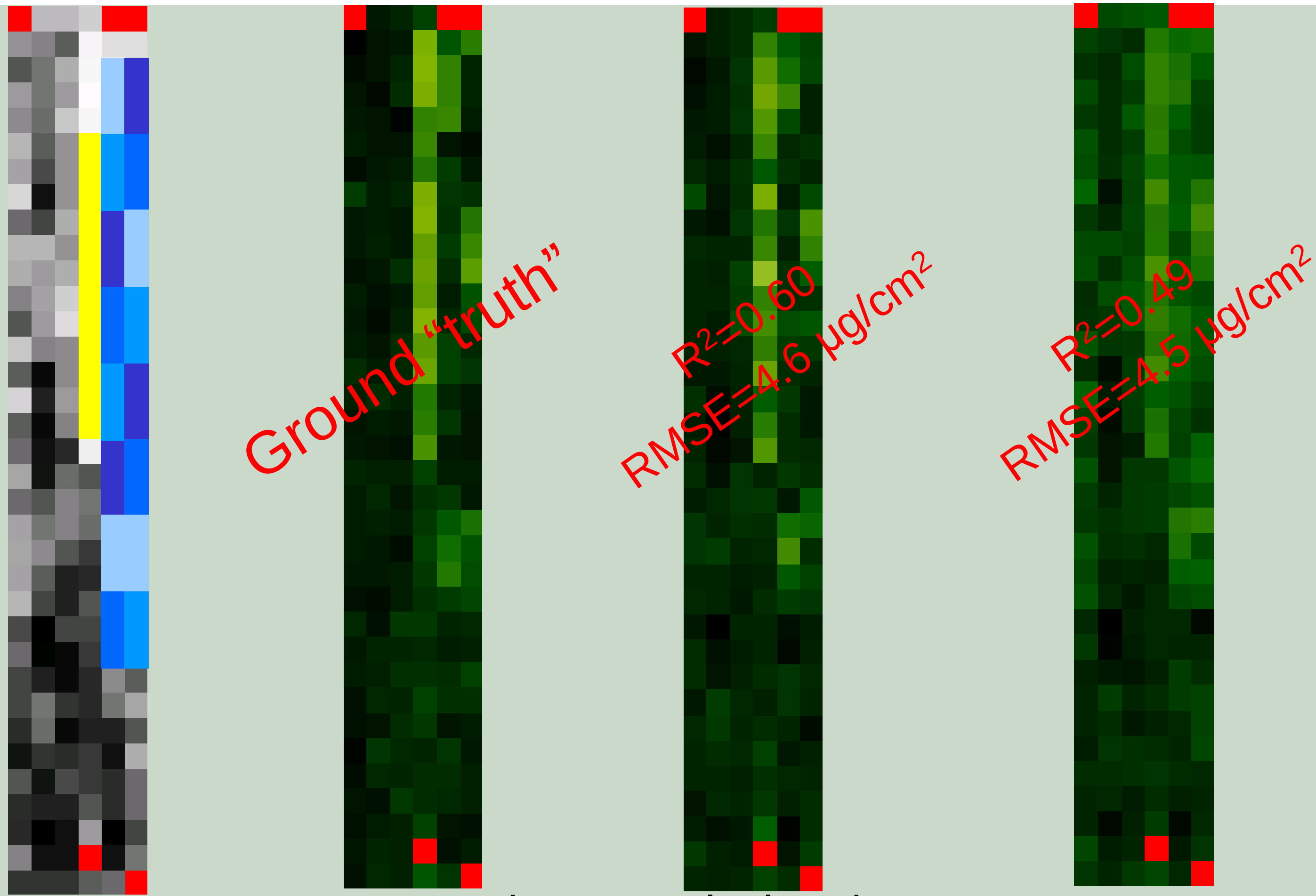
Results Cab retrieval



Treatments

Measured Chlorophyll (**SPAD**)

Calculated Chlorophyll (**regression**)

Calculated Chlorophyll (**model inversion**)

Conclusions

Conclusions

Stress (chlorosis) can be detected on tree and canopy levels

Leaf: R^2=0.95 (regression), R^2=0.81 (inversion)

Canopy: R^2=0.60 (regression), R^2=0.49 (inversion)

Resolution requirements

Spectral requirement: medium (AHS specifications adequate)

Spatial requirement: high (tree-size correpsondence)

Approach

Model inversion < regression (training critical)

Standard inversion < Adapted simulated annealing + filtering

Vegetation indices

Vegetation indices were developed and high correlations were found between iron stress and chlorophyll content

Acknowledgements

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For further information

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