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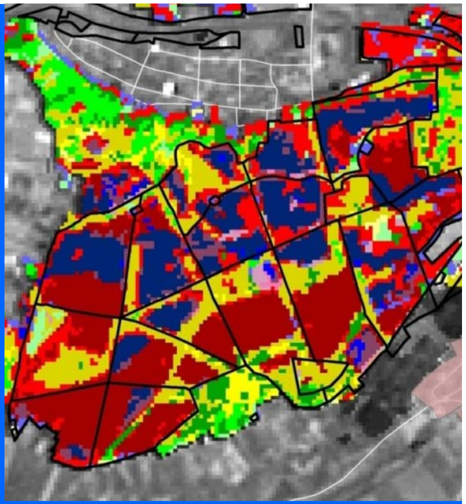

Hyperspectral Forest Remote Sensing:

From operational Forest Management to Process Dynamics of Forest Ecosystems

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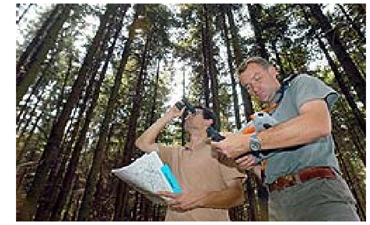
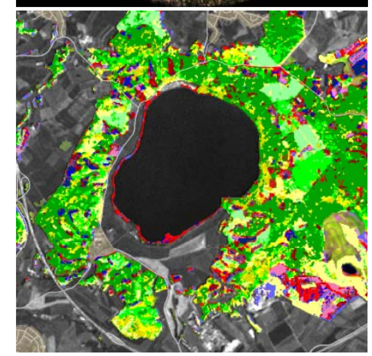
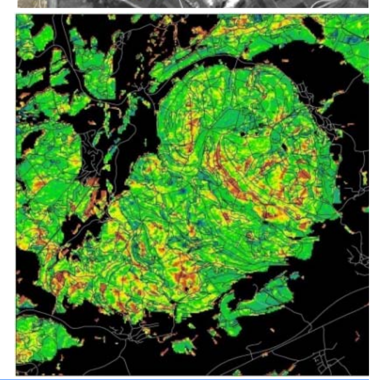
Research focus





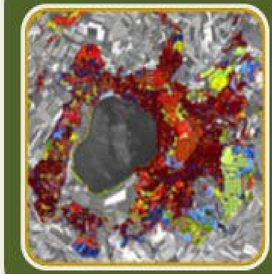


- **Forest Ecosystems**
  - Climate risks: New Species, Water Stress, Changing Site Conditions & Management Strategies
  - Ecophysiological parameters (LAI, Pigment, Water and Nitrogen content, …)
  - Estimation of Productivity and Carbon Balance (NPP, fAPAR, …), Growth Simulators
  - Regional Water Balance
- **Operative Forest management**
  - Forest Inventory and Mapping (Tree Species, Age classes, Calamities…)
  - Combined Procedures for Timber Volume Estimation (regression estimates, k-NN…)
  - GIS-based Habitat Analysis

Levels of Forest Remote Sensing

Global Level

- Global Forest Monitoring
- Global biogeochemical cycles
- Tropical Forest Monitoring
- Forest Fire Monitoring



Regional Level

- National Forest Inventories
- Forest damage mapping
- Timber mobilisation

Stand Level

- Stuctural stand parameters
- Biochemical stand parameters
- Forest damage mapping
- Timber mobilisation

Suitability of Remote Sensing Methods for National Forest Inventories was shown in several studies.

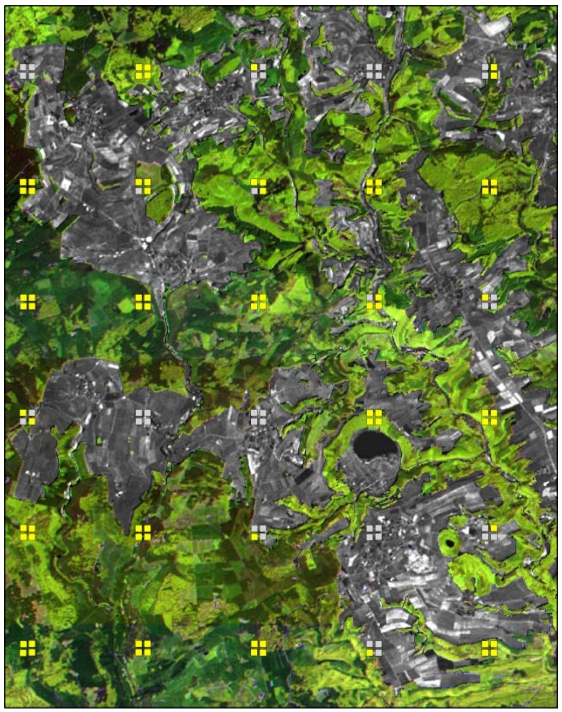
But only the Scandinavian countries use satellite imagery as a standard tool in their national Forest Inventories.

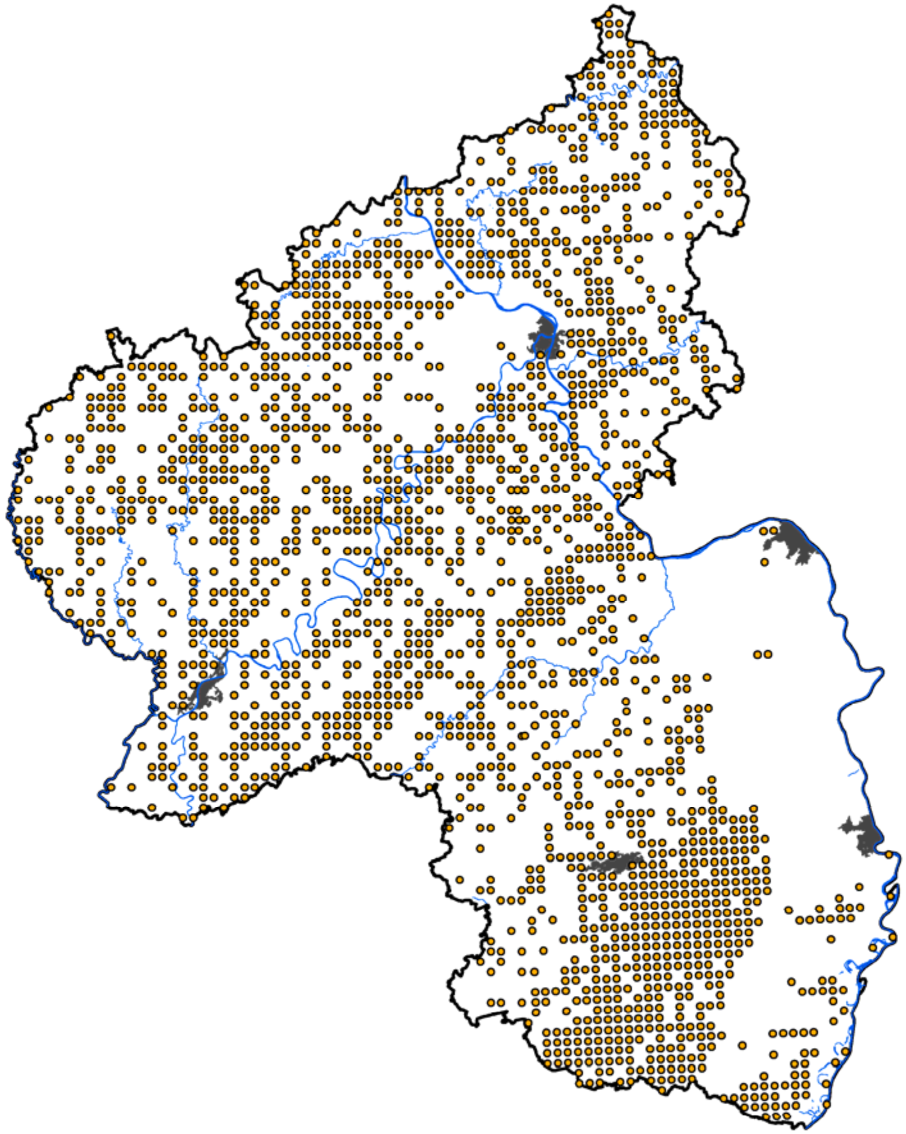
In Germany most studies only cover single forest administrations.

Forest Inventory / Classification

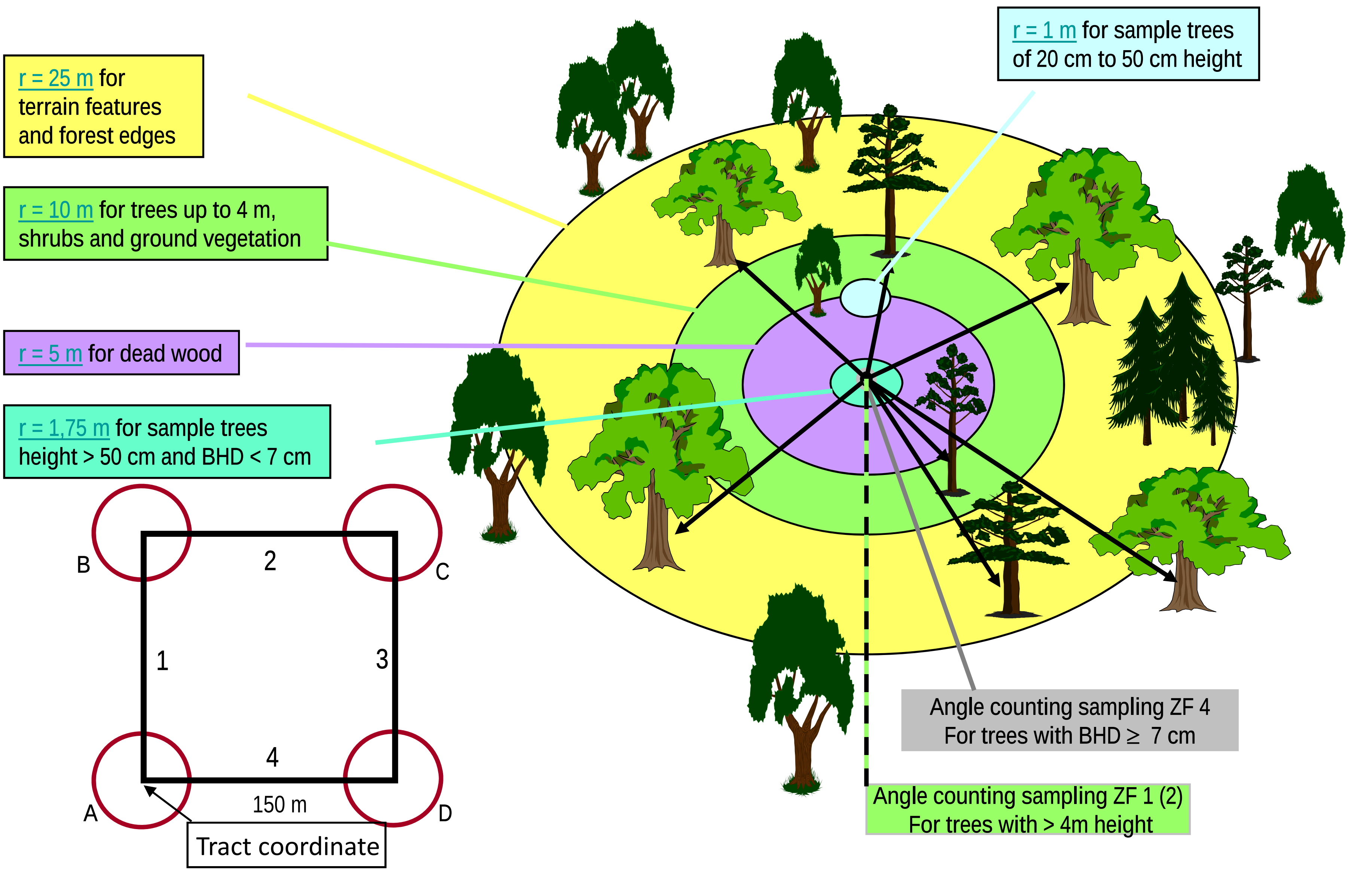
The state forest Inventory only samples in 2x2 and 4x4 km Rasters

("Bundeswaldinventur" and "Landeswaldinventur")





Forest Inventory / Classification



Forest Inventory / Classification

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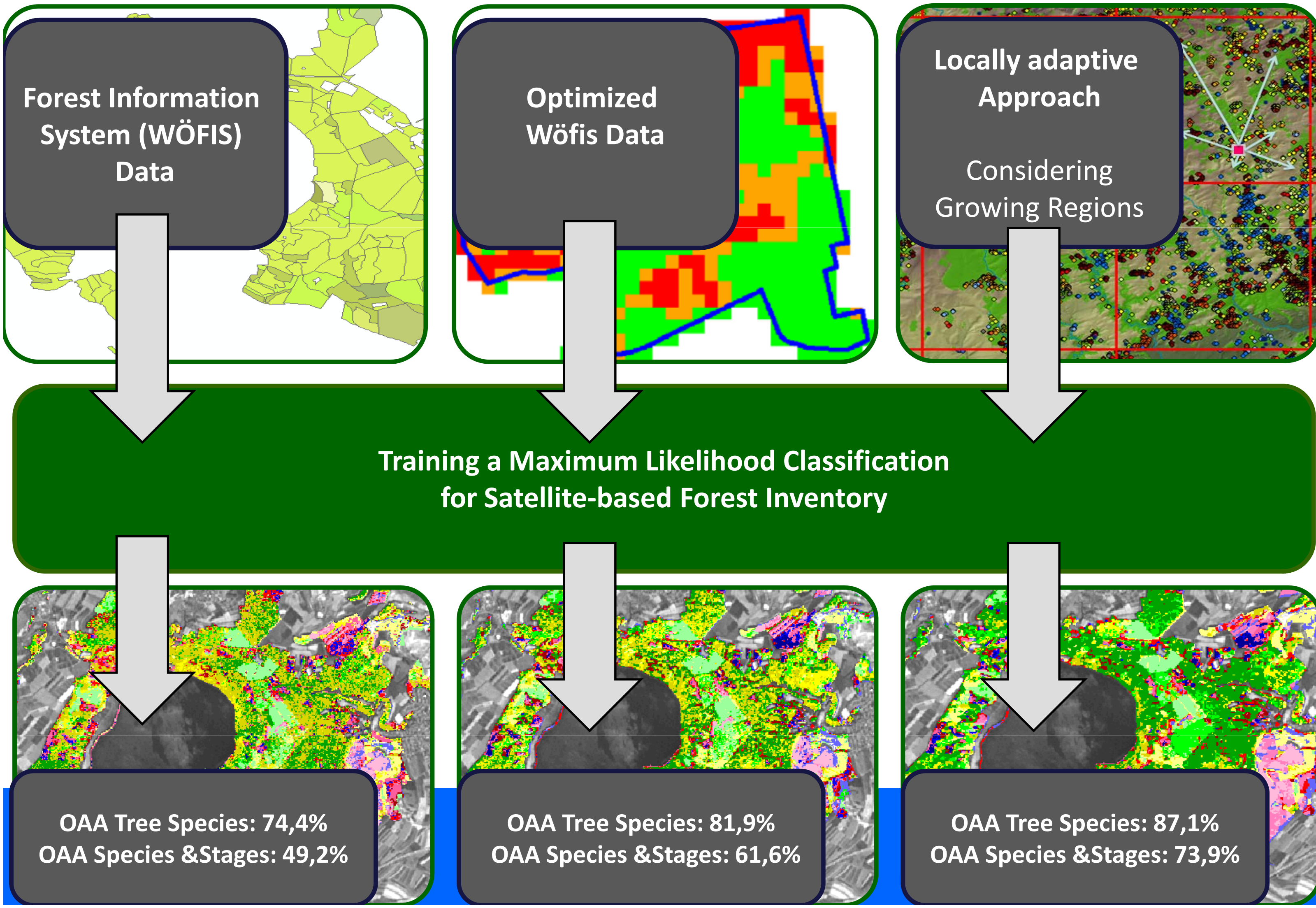
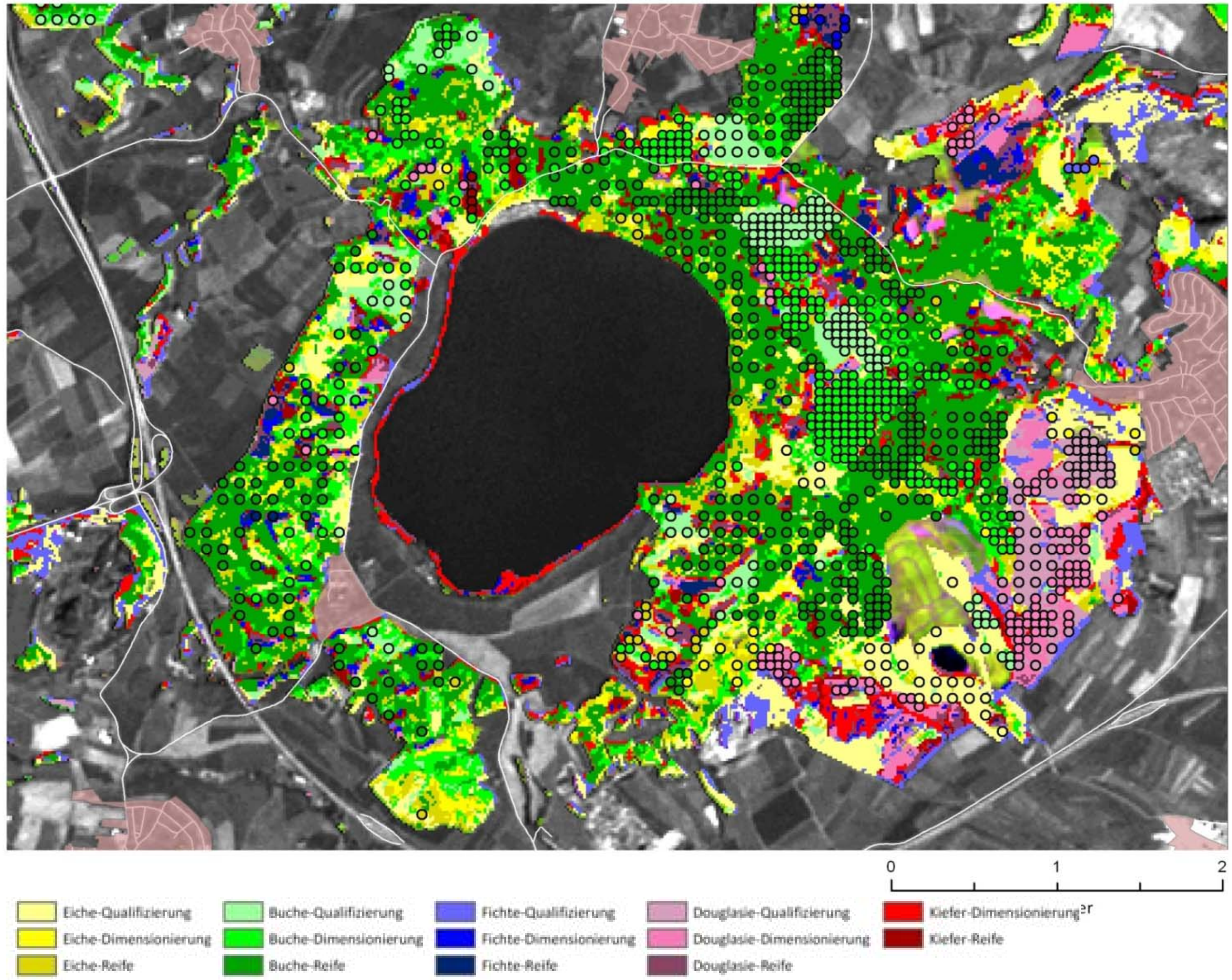
A forest inventory at regional scale was conducted using ASTER and SPOT data. The accuracy at first was not satisfactory, but could be improved by optimizing the calibration data and by applying a locally adaptive training stage.



Forest Inventory / Classification

Accuracy Assessment at regularly spaced points



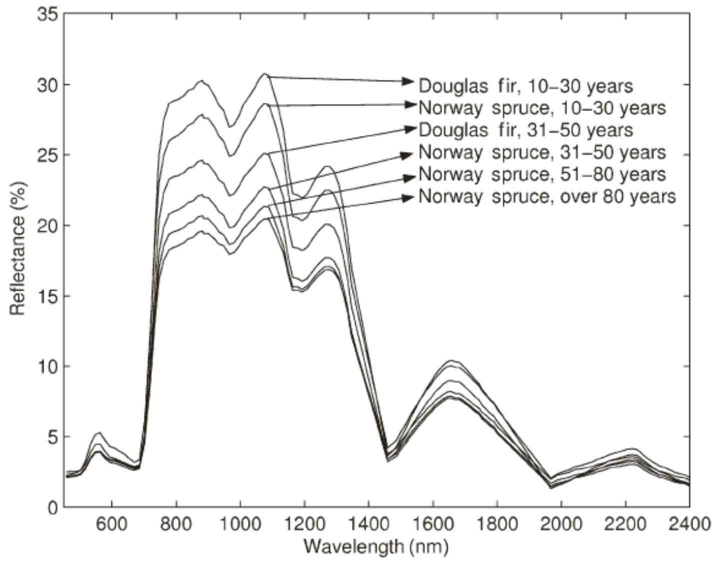
Datengrundlage:
Klassifikationsergebnis der satellitengestützten Waldinventur in der Osteifel. Im Hintergrund: ASTER-Satellitenbilddaten vom 26.06.2001 und 02.04.2005, Waldökologisches Forstinformationssystem (Landesforsten RLP), ATKIS-Walddaten (LVermGeo RLP)

PhD Thesis J. Stoffels 2009

Forest Inventory / Classification

Improved Classification by

- Good Geometric and Radiometric correction
- Multi-phenological input data
- Optimised reference data
- Locally adaptive Classification
- Hyperspectral imagery
- Classification algorithms like SVM
- Object-based
- Texture
- Subpixel Classification / Spectral Unmixing
- Complementary Data like Lidar, Radar



Classification using hyperspectral & texture data

Buddenbaum, Schlerf & Hill: IJRS 2005

Fusioning Hyperspectral and Laserscanning data

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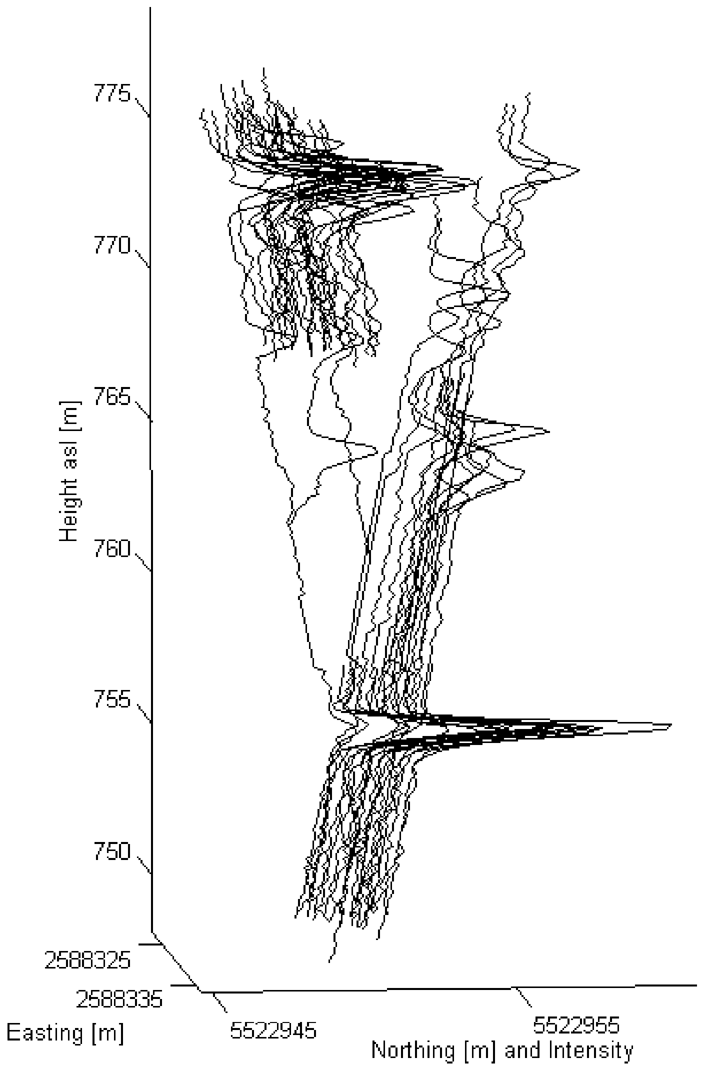
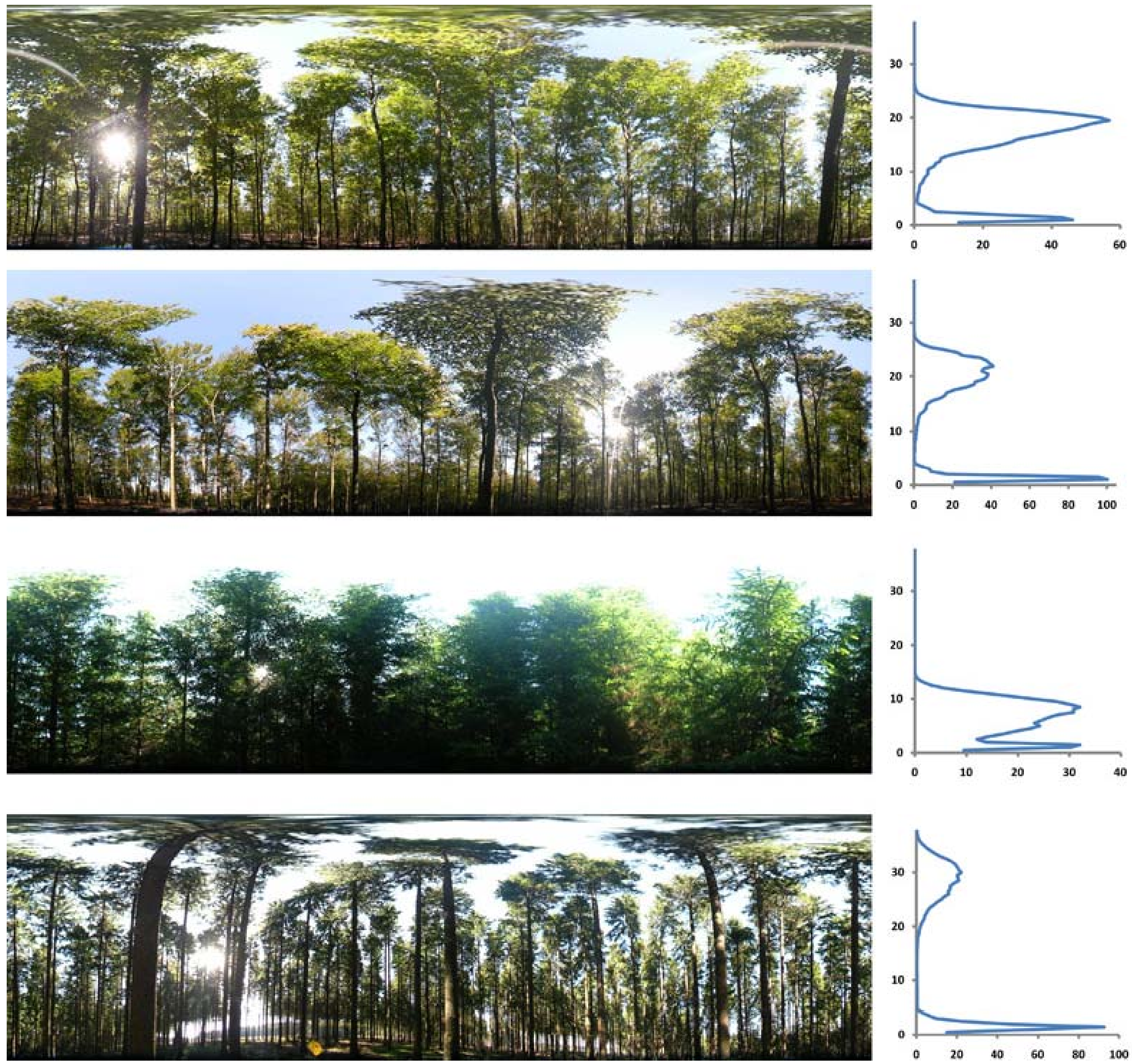
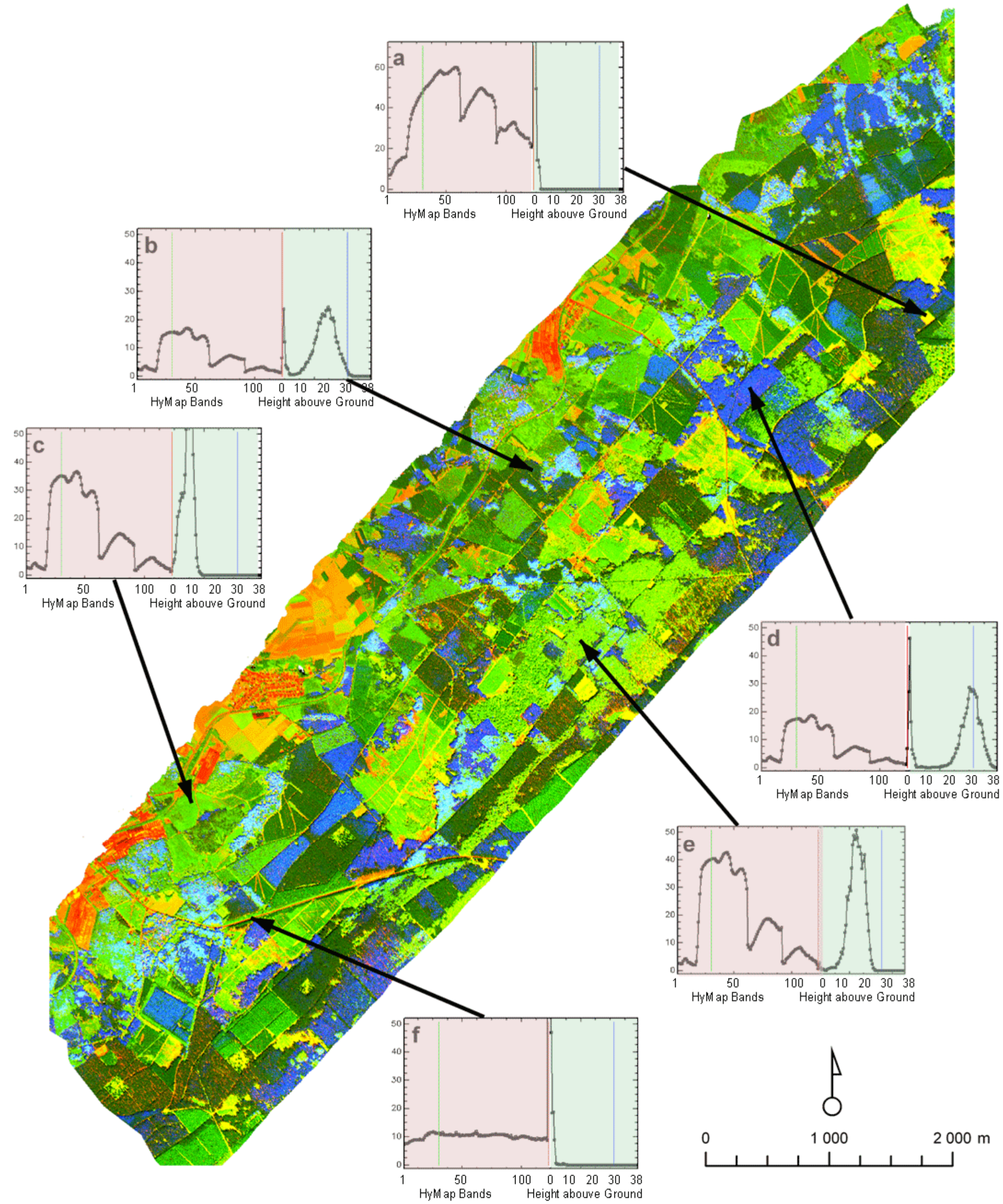
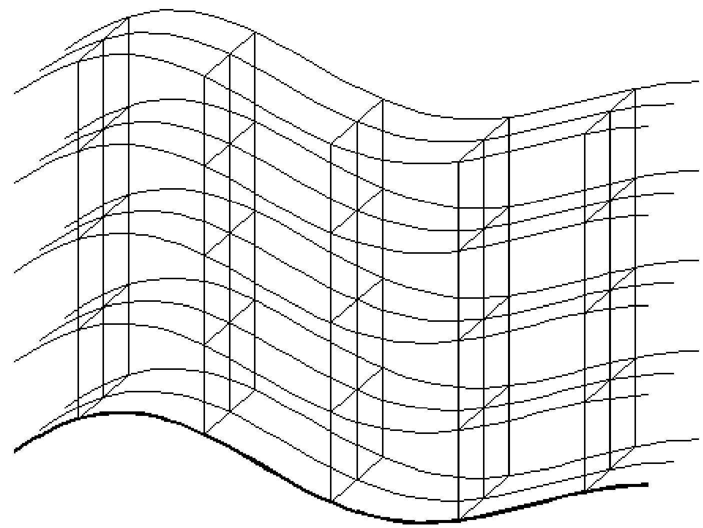




Fusioning Hyperspectral and Laserscanning data

Universität Trier Remote Sensing Department





The waveform data was arranged into 5m x 5m x 50cm voxels containing the mean intensity

Buddenbaum & Seeling (2008)

Charakterisierung von Forstbeständen mit Hilfe von Laserscanning und Reflexionsmodellierung, Diss. Uni Trier, Buddenbaum (2009)

Quantitative Measurements

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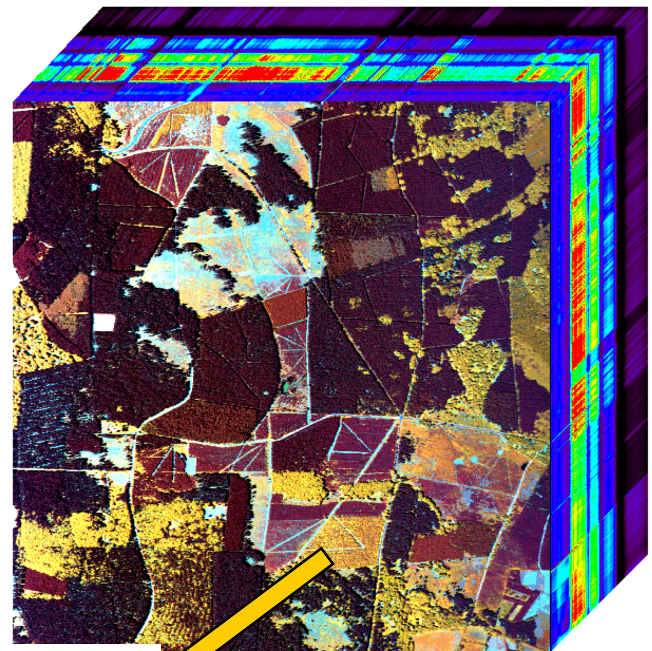
Spatially differentiated, quantitative Determination of

- **Leaf and Needle Losses, Chlorosis, Crown cover, Age structure of Forest Stands**
- **Biophysical properties of Forest Stands (LAI, Cab, Cw)**

Empirical-statistical ↔ Model-based Approaches

HyMap Data Cube FA Morbach



DLR

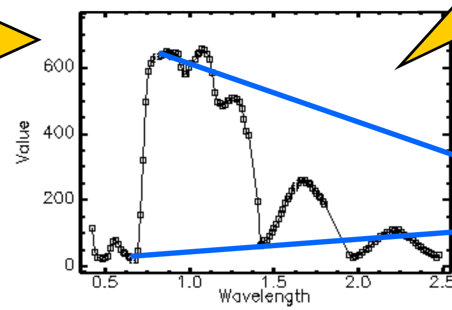
Reflection model

$\rho_{mod(l)} = f(\theta, LAI, C_{ab}, C_w, \ldots)$

Model Inversion

LAI, C_{ab}, C_w, ...

$$F = \Sigma [\rho_{mod(l)} - \rho_{meas(l)}]^2 \Rightarrow min$$

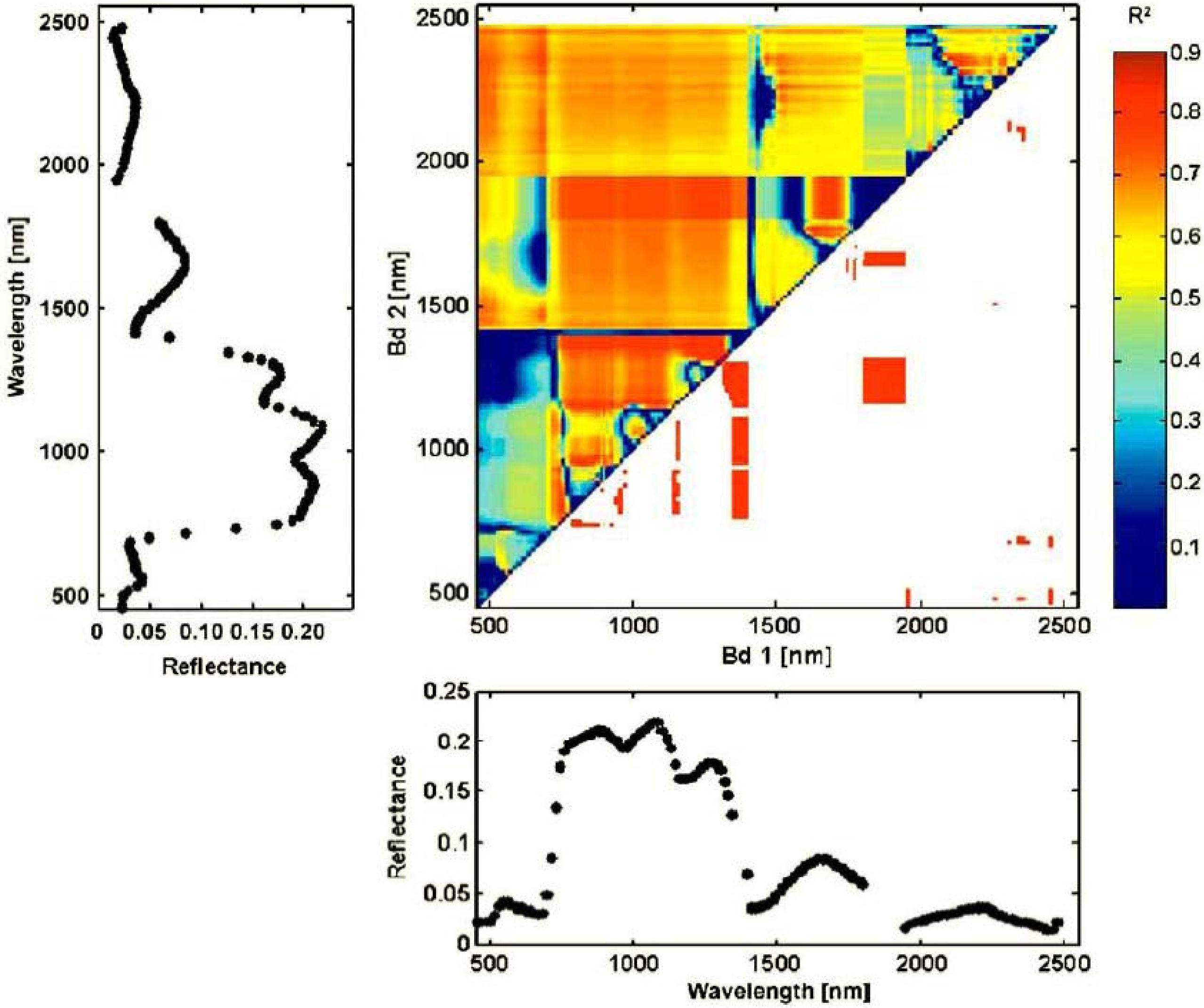


$$NDVI = \frac{\rho_{nIR} - \rho_{red}}{\rho_{nIR} + \rho_{red}}$$

Empirical-statistical approaches: Indices

With hyperspectral data, one way to estimate quantitative canopy variables is using narrow-band indices.

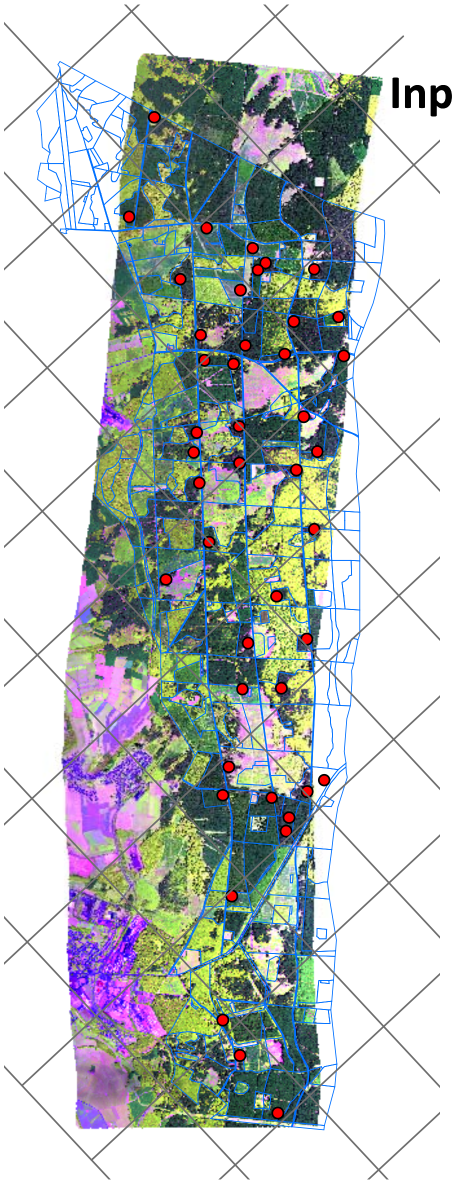
With 126 HyMap bands there are 15625 possible combination for 2 band indices.

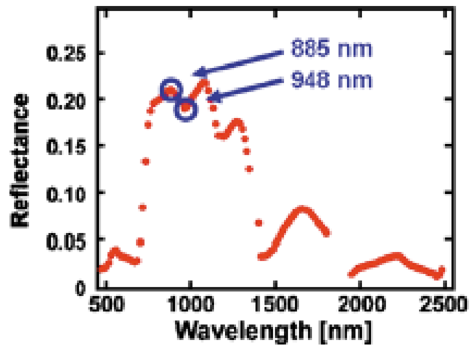


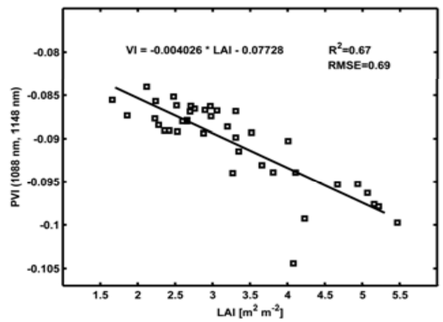
Schlerf, Atzberger & Hill: RSE 2005

Empirical-statistical quantitative approaches: LAI

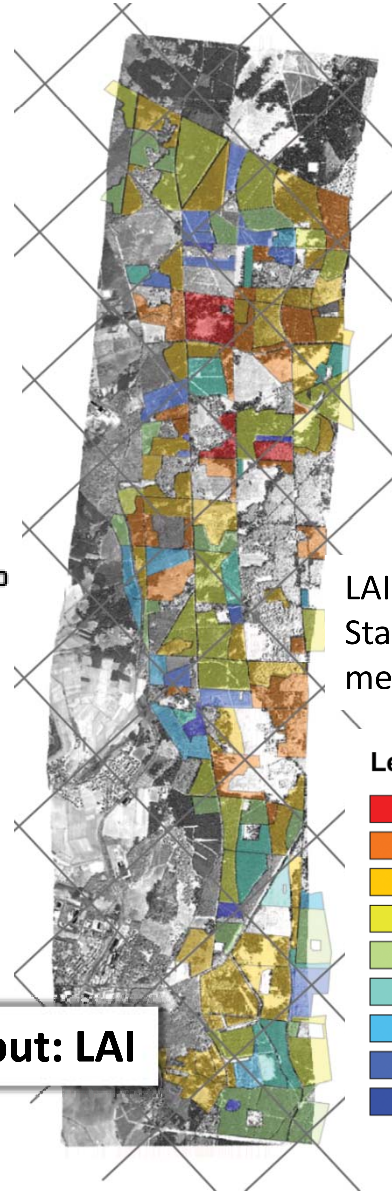
Input: HyMap







Output: LAI



Empirical modelling of LAI in spruce forests (Idarwald Forst, Germany)

LAI [m^2 m^{-2}] Stand means

Legend

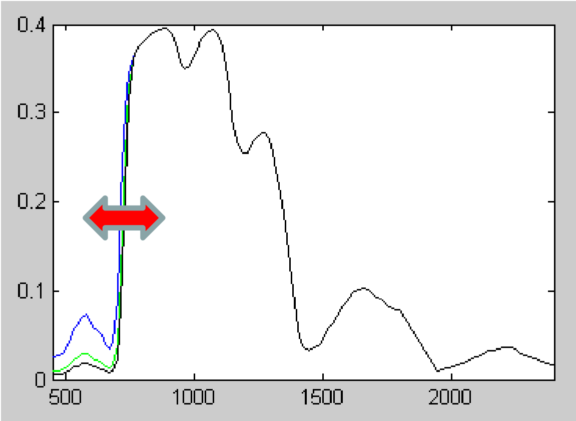
- < 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- > 5.5

PhD Thesis M. Schlerf 2005

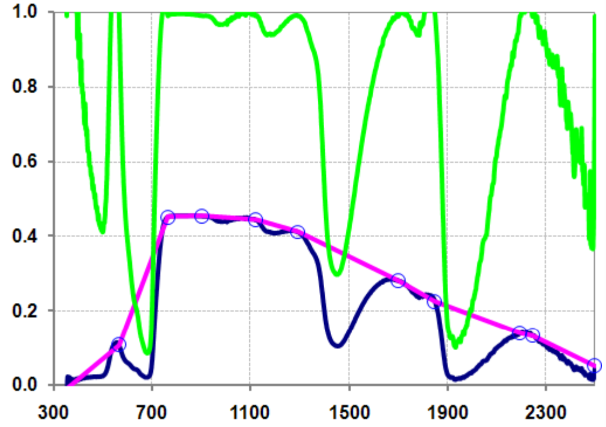
Empirical-statistical approaches

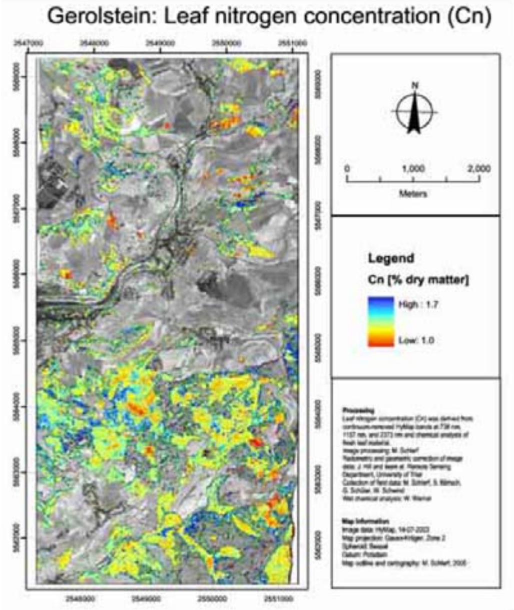
Many more things can be done with hyperspectral data…

Red Edge Inflection Point



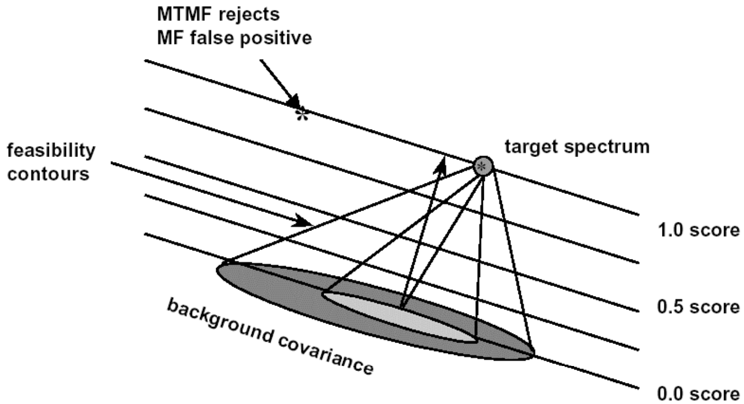
Convex Hull / Continuum Removal



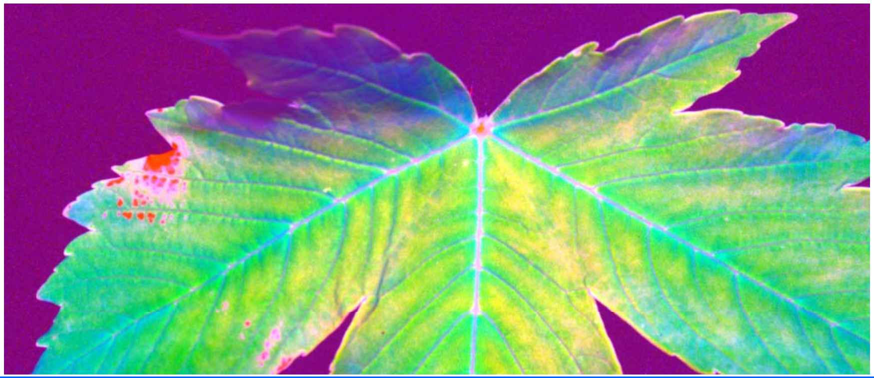


Schlerf, Atzberger, Hill, Buddenbaum, Werner & Schüler (2009)

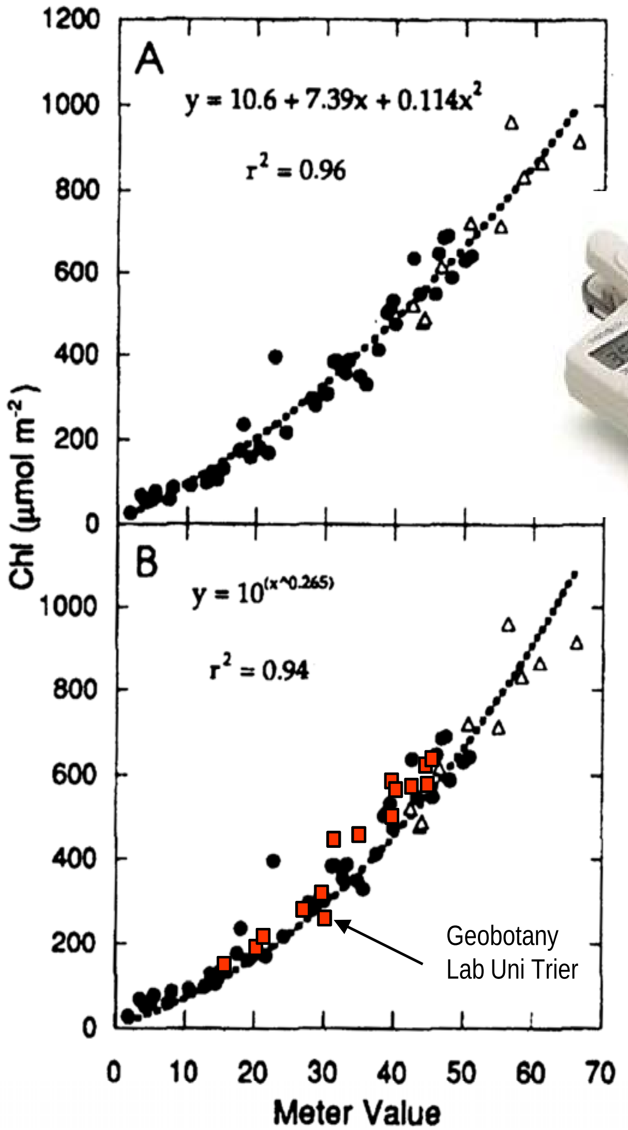
Mixture-tuned matched filtering



MNF transformation

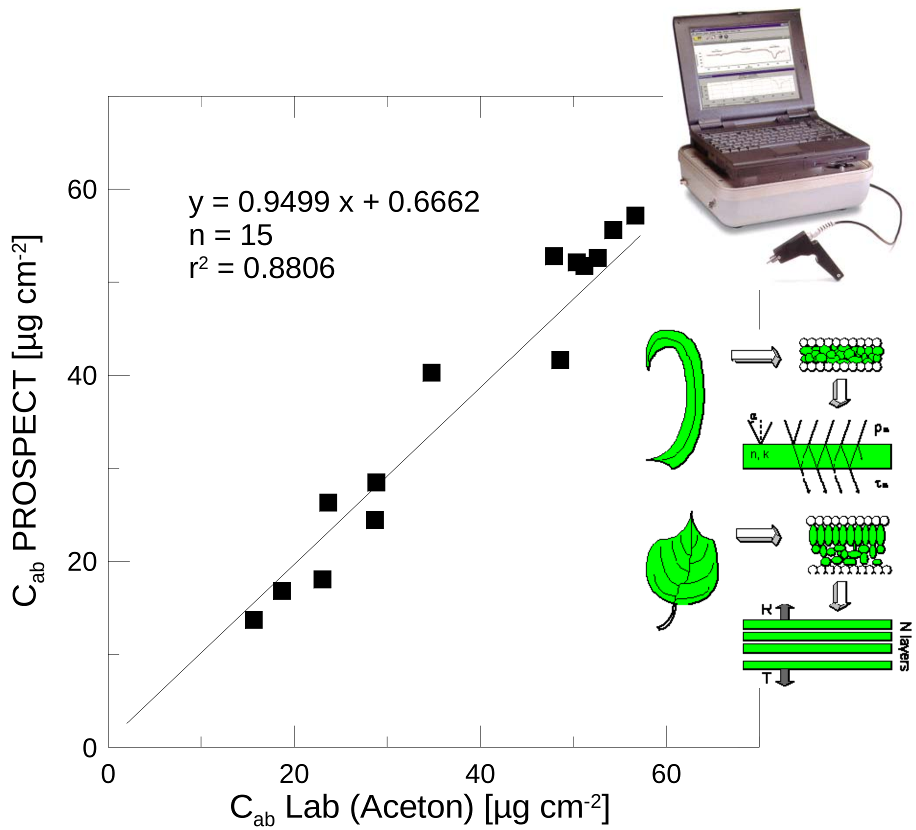


Model-based approaches: Chlorophyll



Minolta SPAD-502 chlorophyll meter

Chlorophyll concentration Beech & Oak

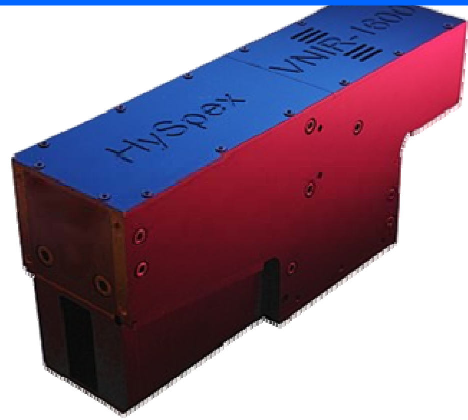


Lab (Aceton) vs. PROSPECT

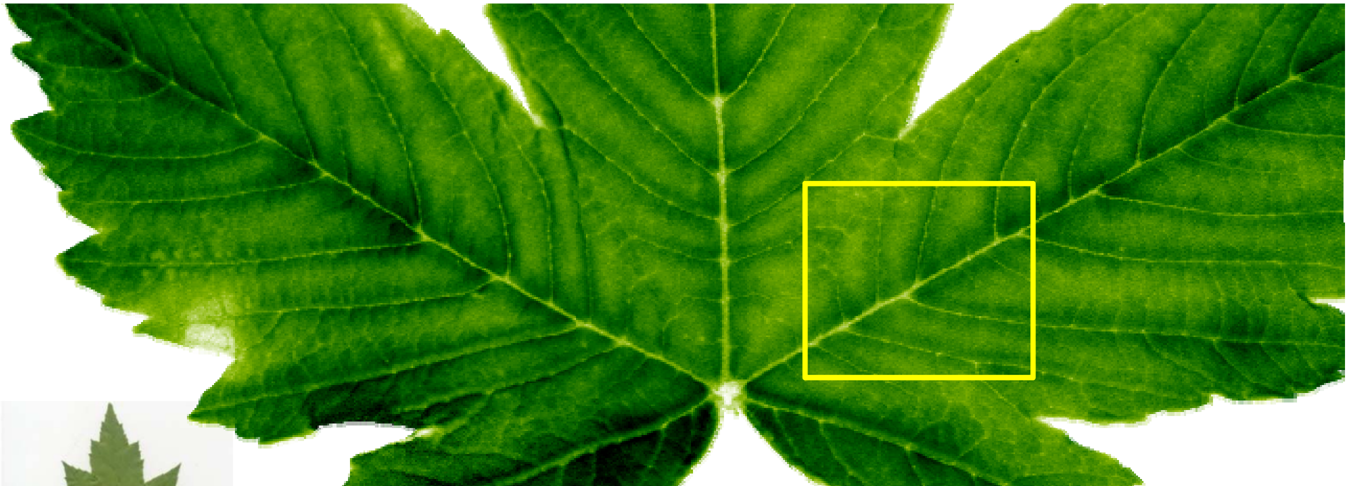
Markwell et al. (1995)

Chlorophyll measurements

Universität Trier Remote Sensing Department

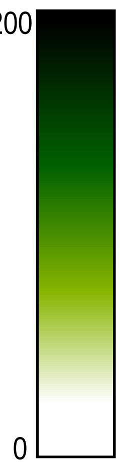


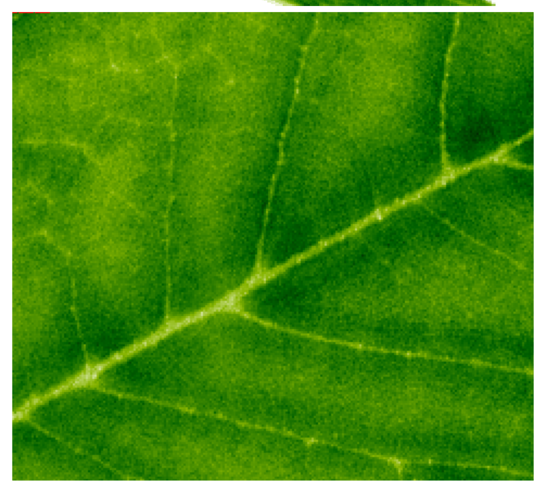
Min: 0 Mean: 72.04
Max: 180.04 Stdev: 13.36



Total Chlorophyll [µmol m^{-2}]

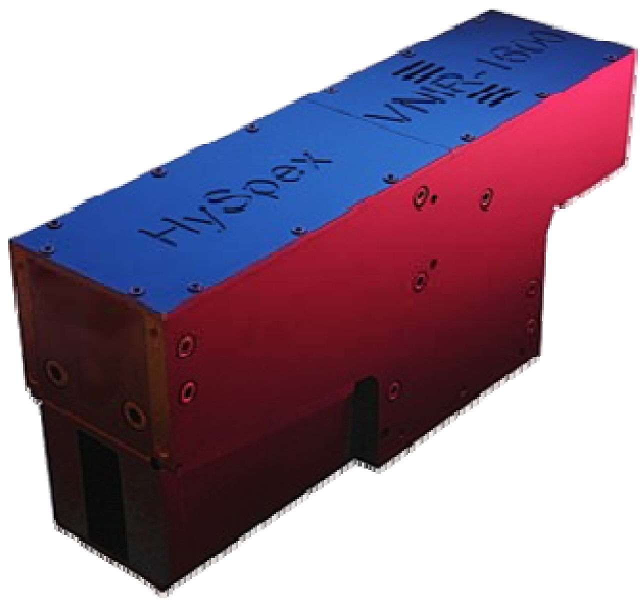
(Gitelson et al. 2003)

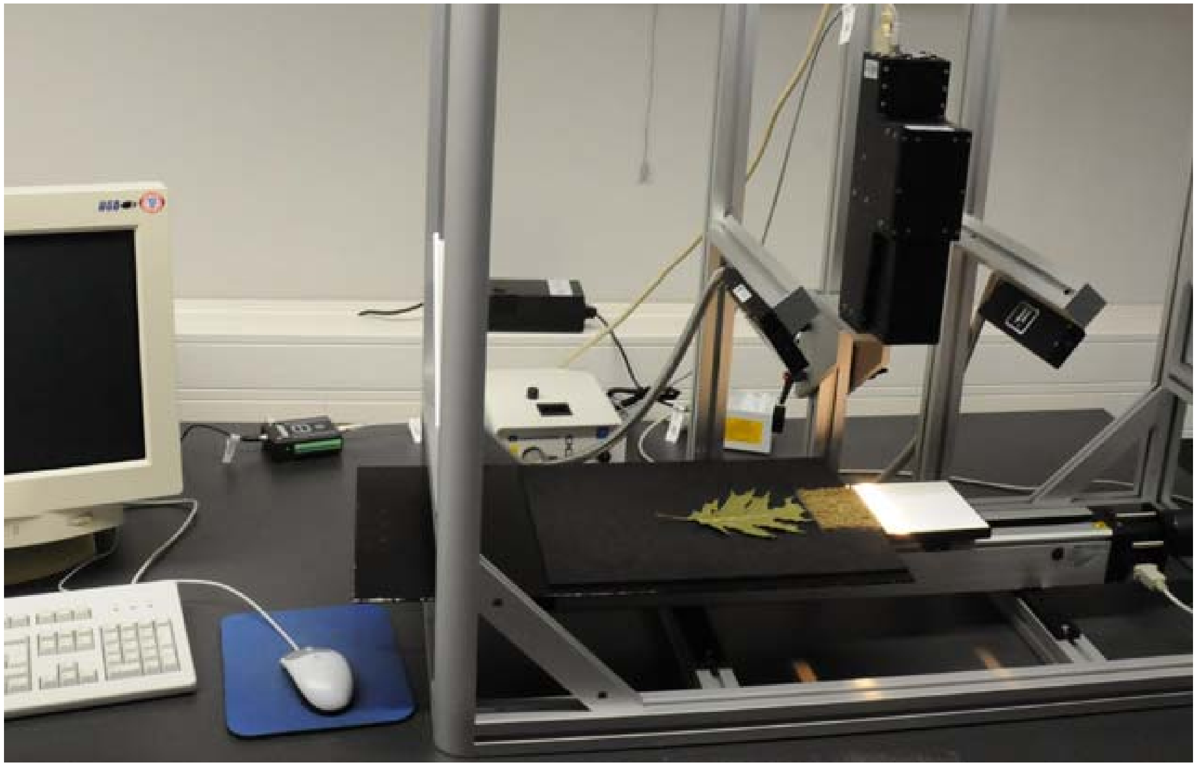


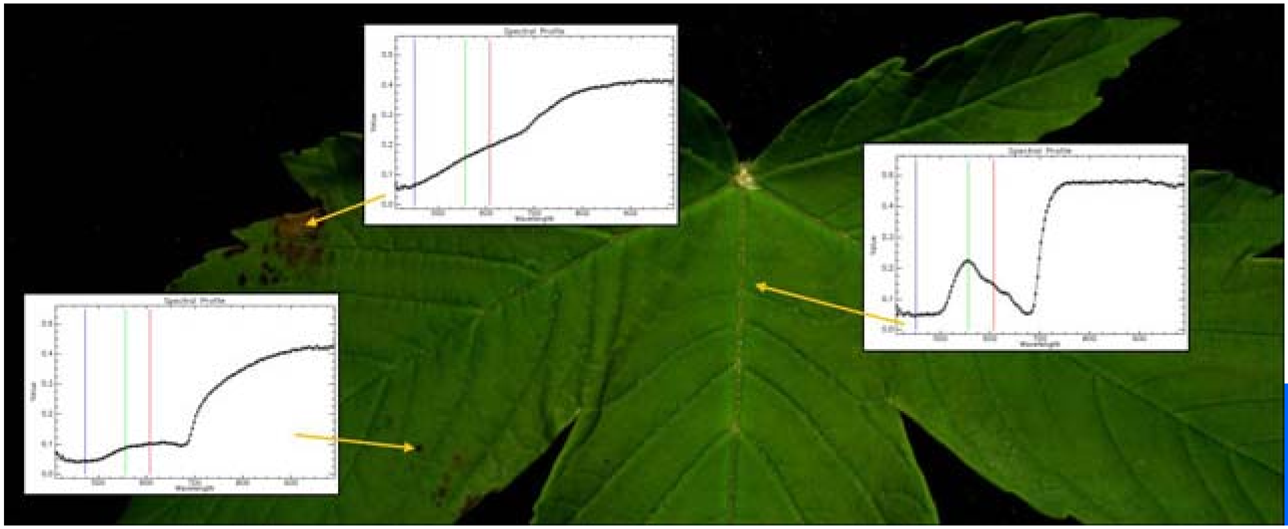


Gitelson, A.A., Gritz, Y., & Merzlyak, M.N. (2003). Relationships between leaf chlorophyll content and spectral reflectance and algorithms for non-destructive chlorophyll assessment in higher plant leaves. *Journal of Plant Physiology, 160, 271-282.*

Hyperspectral Laboratory Imaging



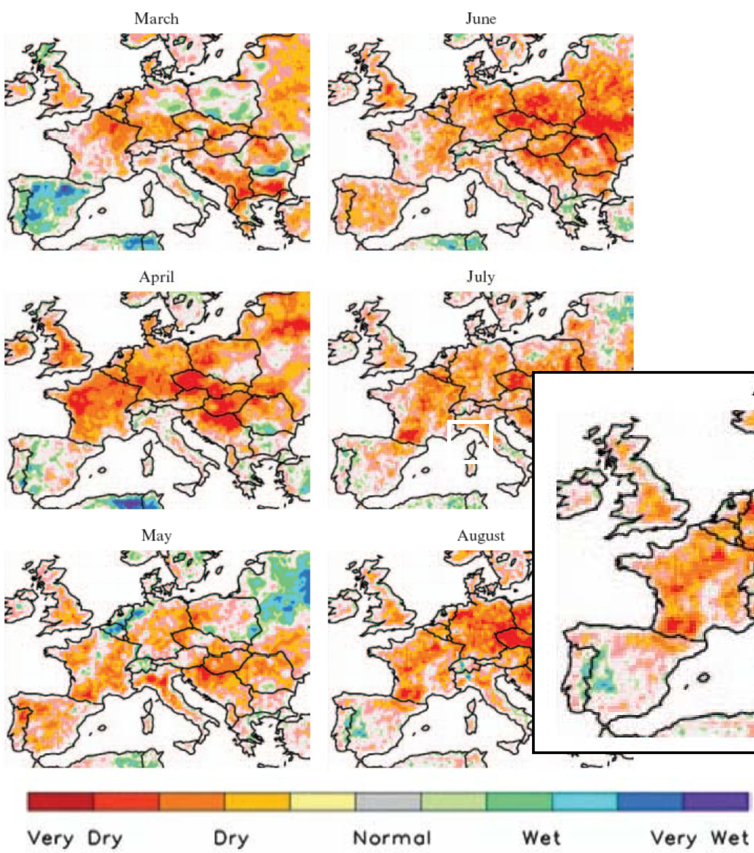




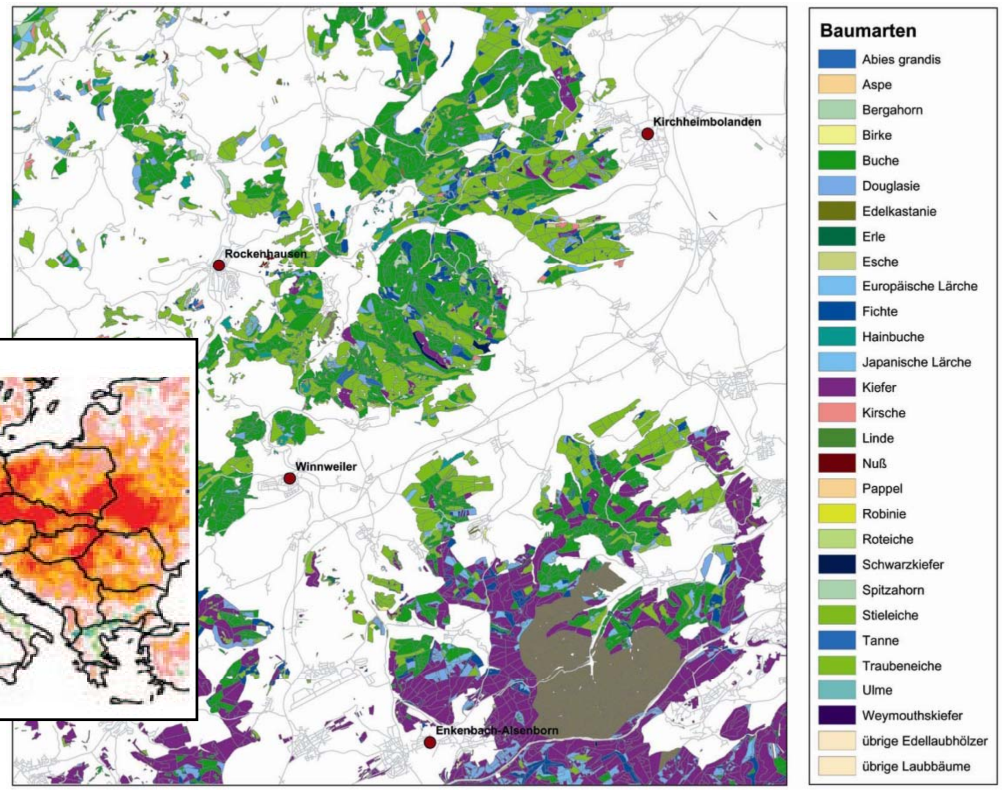
HySpex (Norsk Elektro Optikk AS)
Hyperspectral Line Scanner
1600 columns x 160 bands
400 – 1000 nm
@ 3.7 nm spectral sampling

Beniston, M. (2004): The 2003 heat wave in Europe: A shape of things to come? An analysis based on Swiss climatological data and model simulations, Geophysical Research Letter, 31.

Background: Donnersberg 2003: Impact of Drought Stress

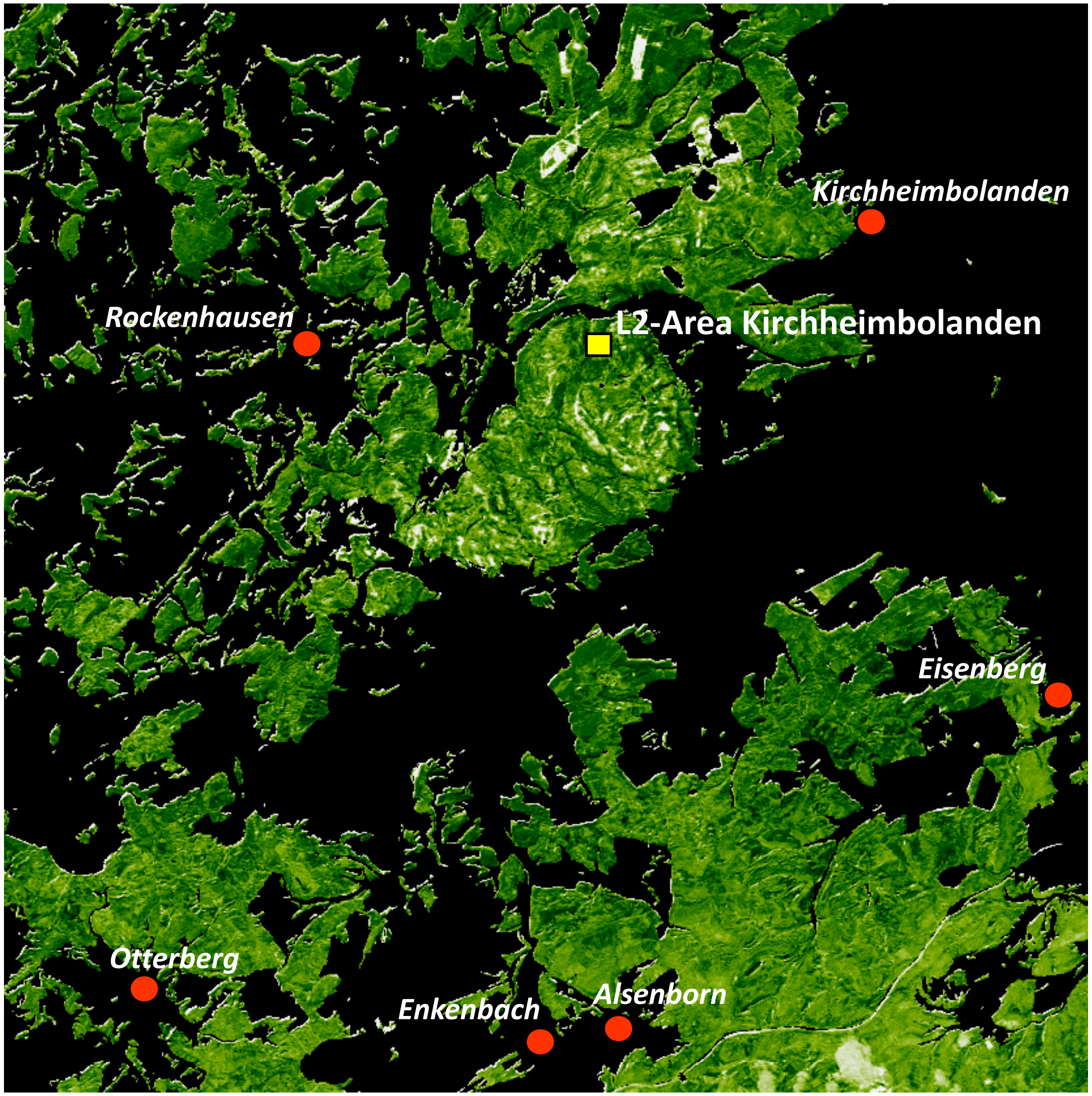


Experimental Wetness Indicator derived from the SSM/I sensor (see http://lwf.ncdc.noaa.gov/), showing monthly anomalies for 2003 with respect to the base period 1988–2002 [from Gobron et al., 2005].



Source: ATKIS, WÖFIS RLP

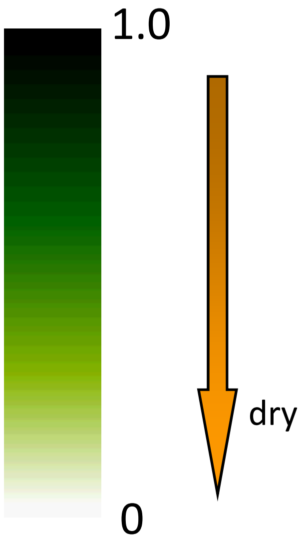
Canopy Water Content in Drought Year 2003



Leaf Water Content Index (LWCI) from Landsat TM

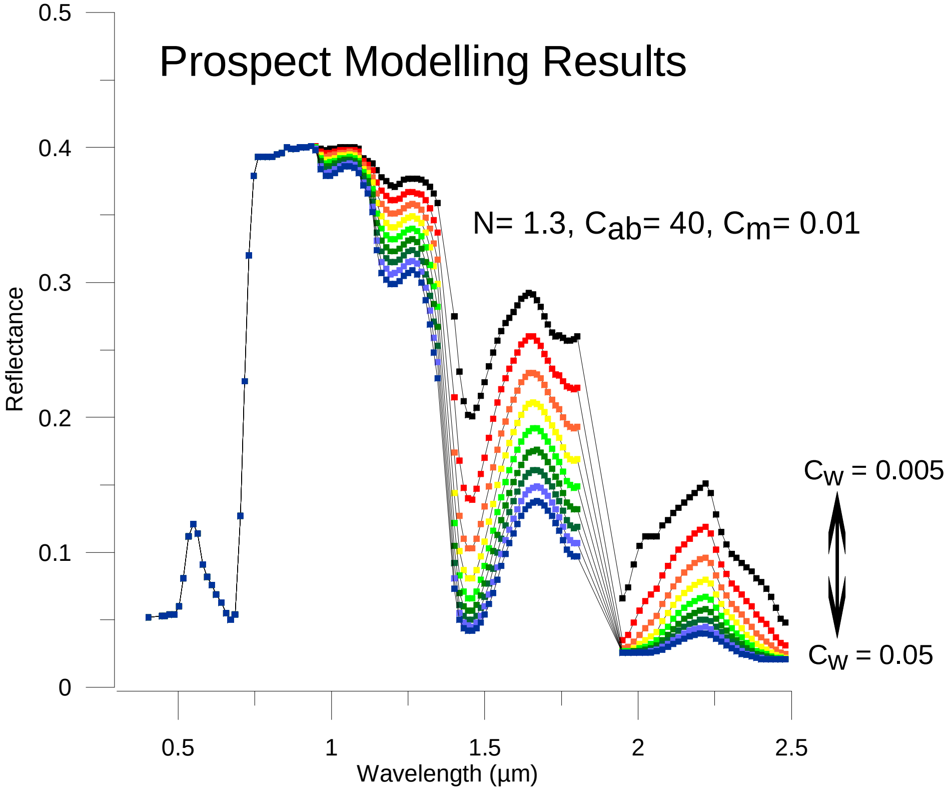
$$LWCI = \frac{-\log\left[1-\left(TM4 - TM5\right)\right]}{-\log\left[1-\left(TM4_{FT} - TM5_{FT}\right)\right]}$$

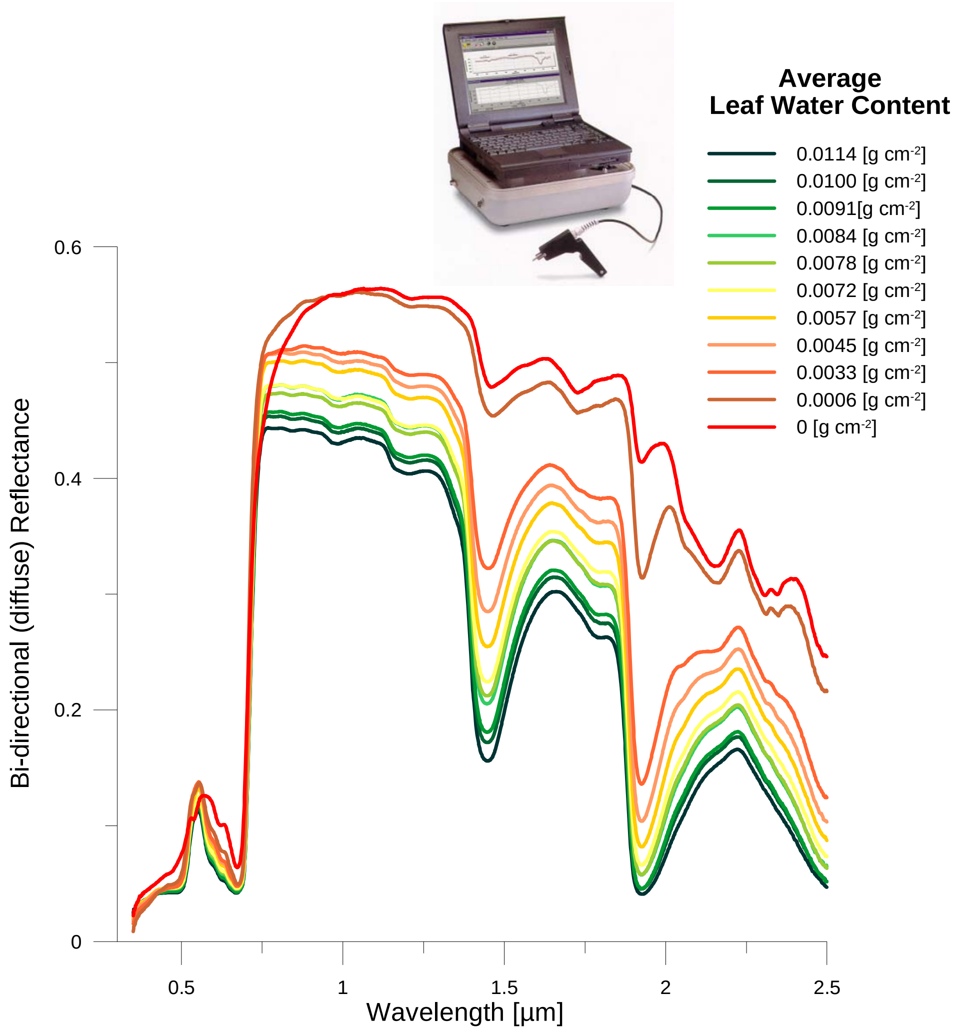
(Hunt et al., 1987)



~ RWC

Leaf Water Content: PROSPECT vs. Measurements

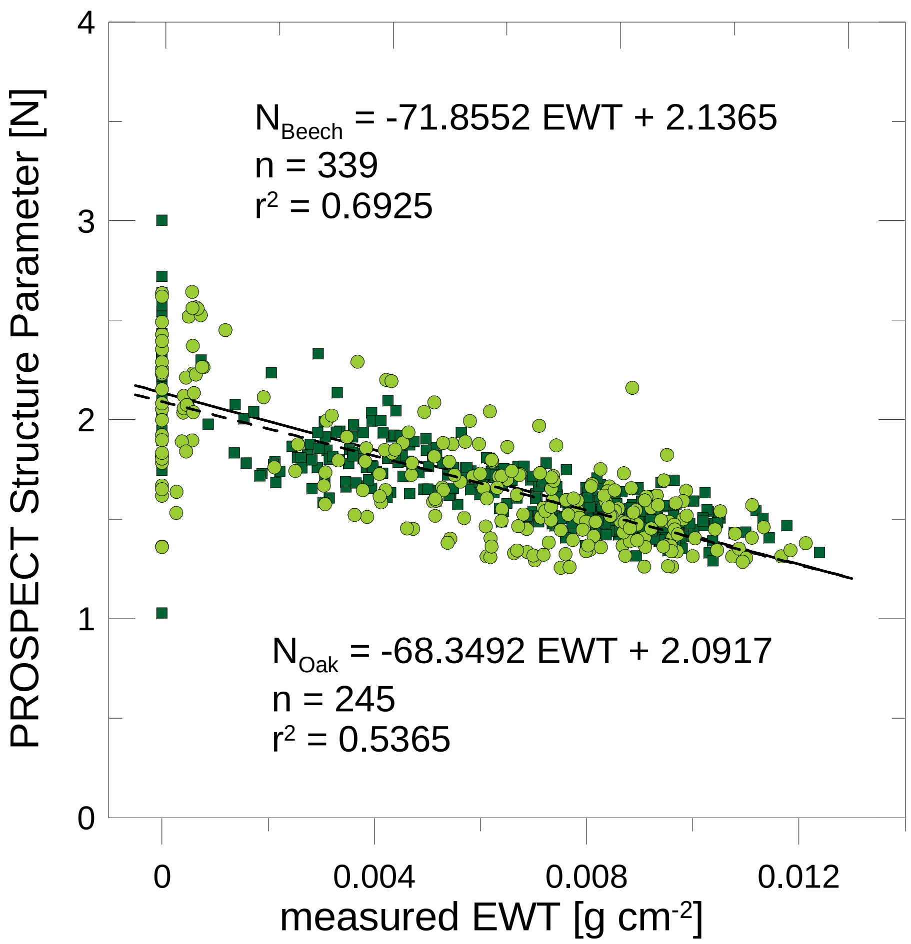




Leaf Water Content: PROSPECT vs. Measurements

Remote Sensing Department, Universität Trier

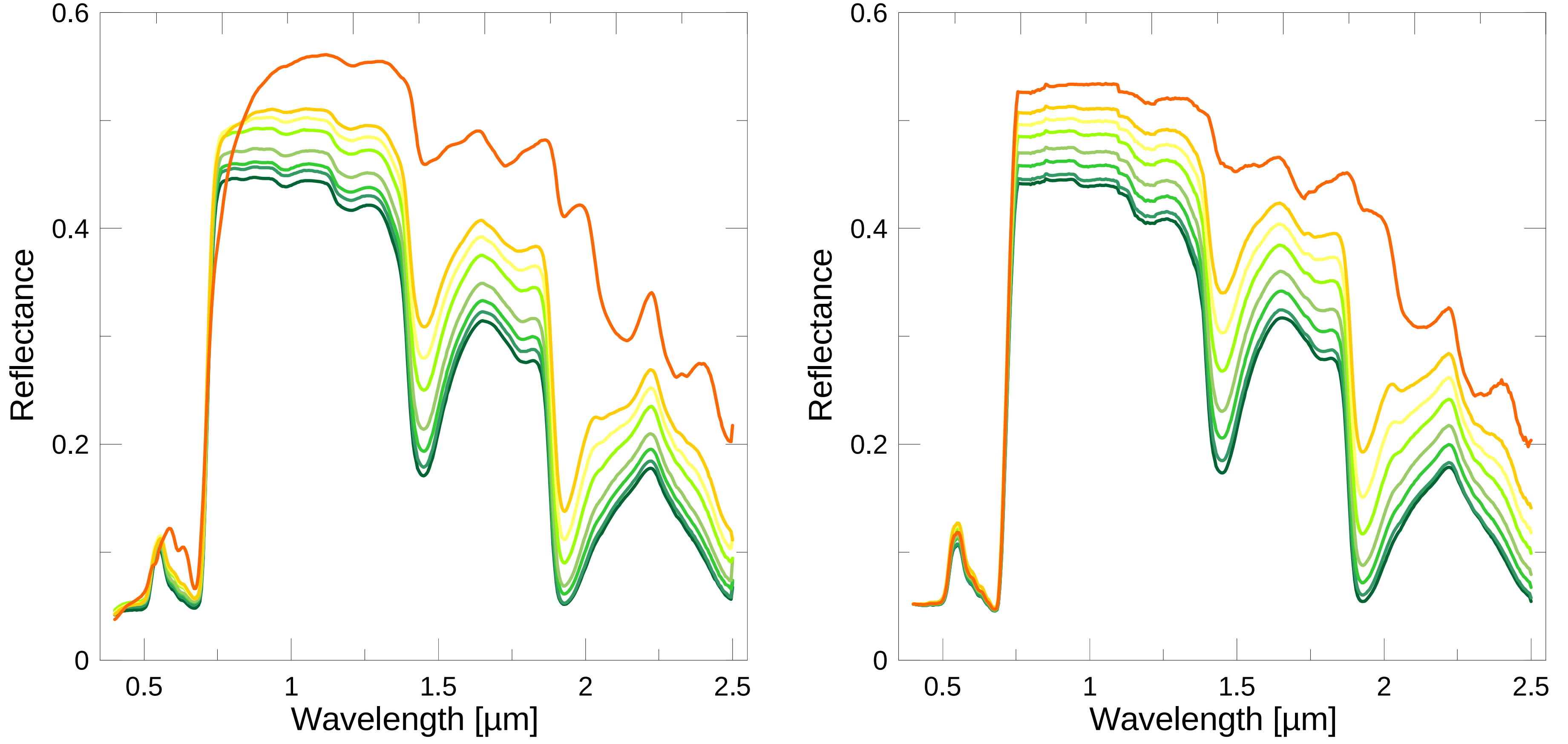
Functional Dependency of PROSPECT Structure Parameter N on the Equivalent Water Thickness (EWT) for Beech and Oak



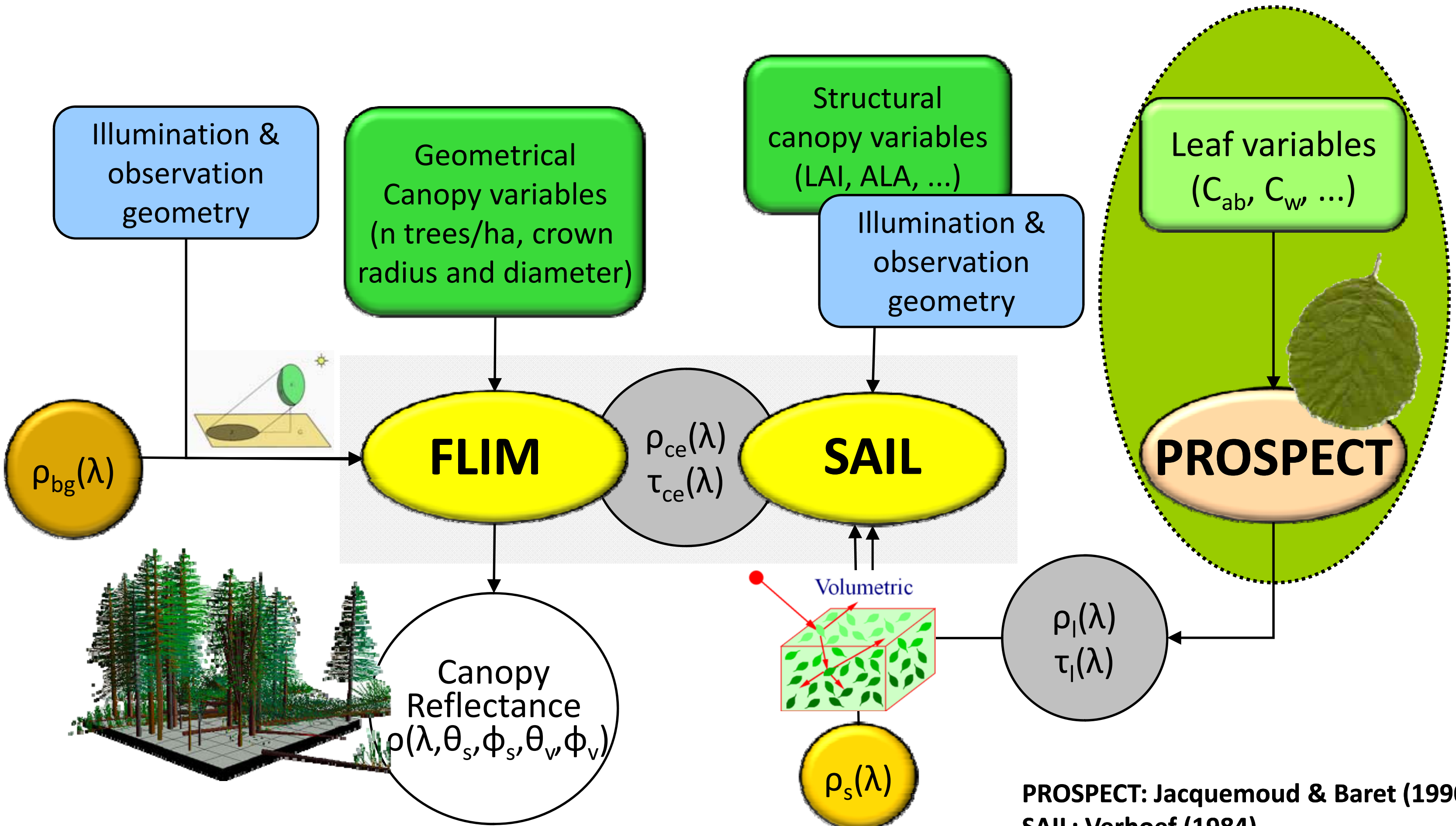
Leaf Water Content: PROSPECT vs. Measurements

Universität Trier Remote Sensing Department

Fagus sylvatica: Measurents vs. Recalibrated Modeling



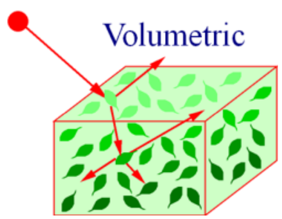
Canopy Reflectance Modelling Concept

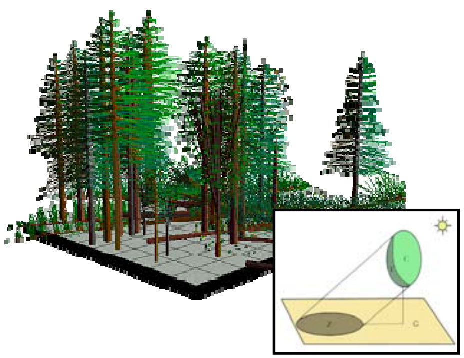


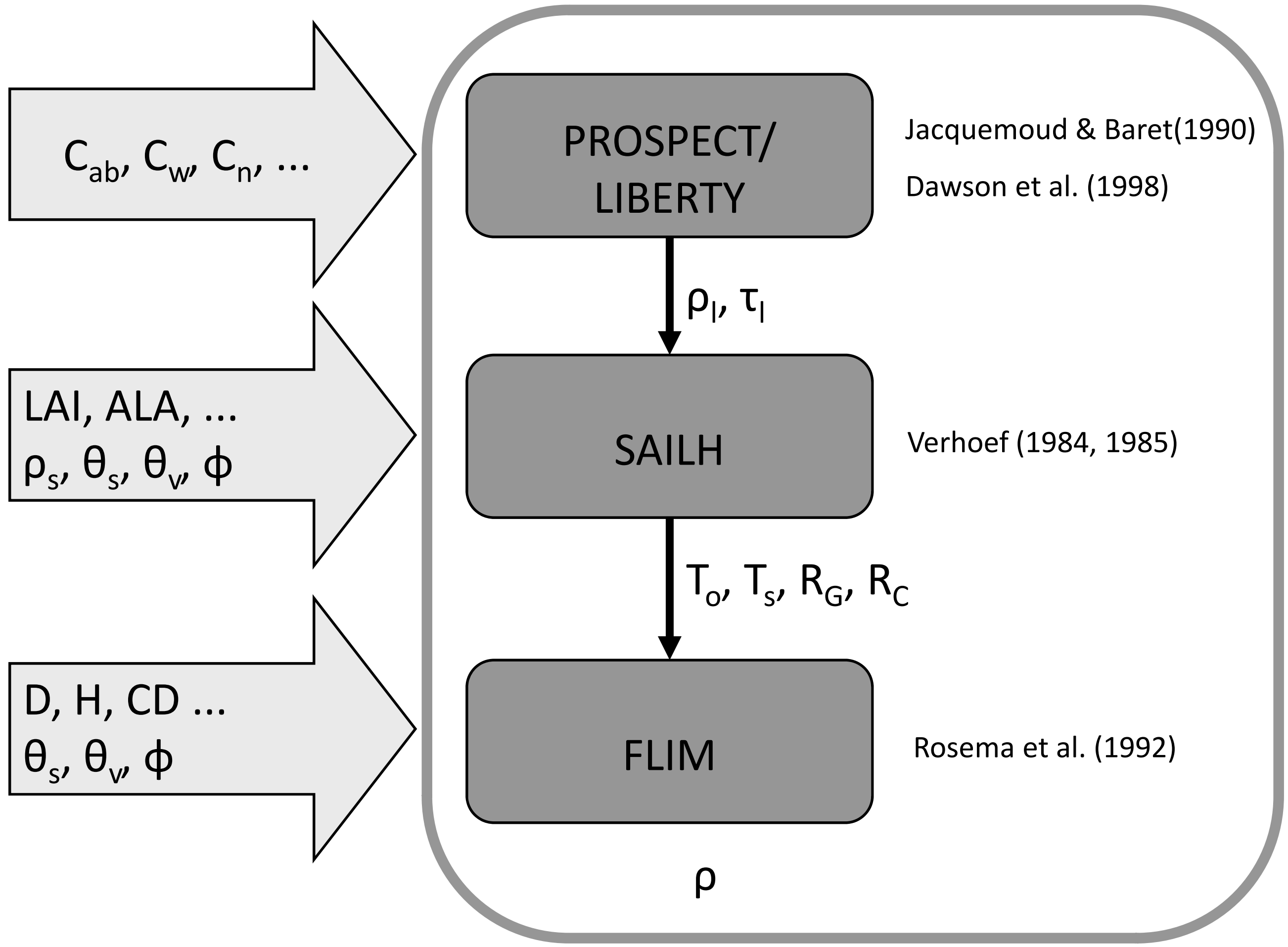
INFORM: Atzberger (2000); Schlerf et al. (2005)

PROSPECT: Jacquemoud & Baret (1990)
SAIL: Verhoef (1984)
FLIM: Rosema et al. (1992)

Geometric Optics Radiative Transfer Modelling Concept



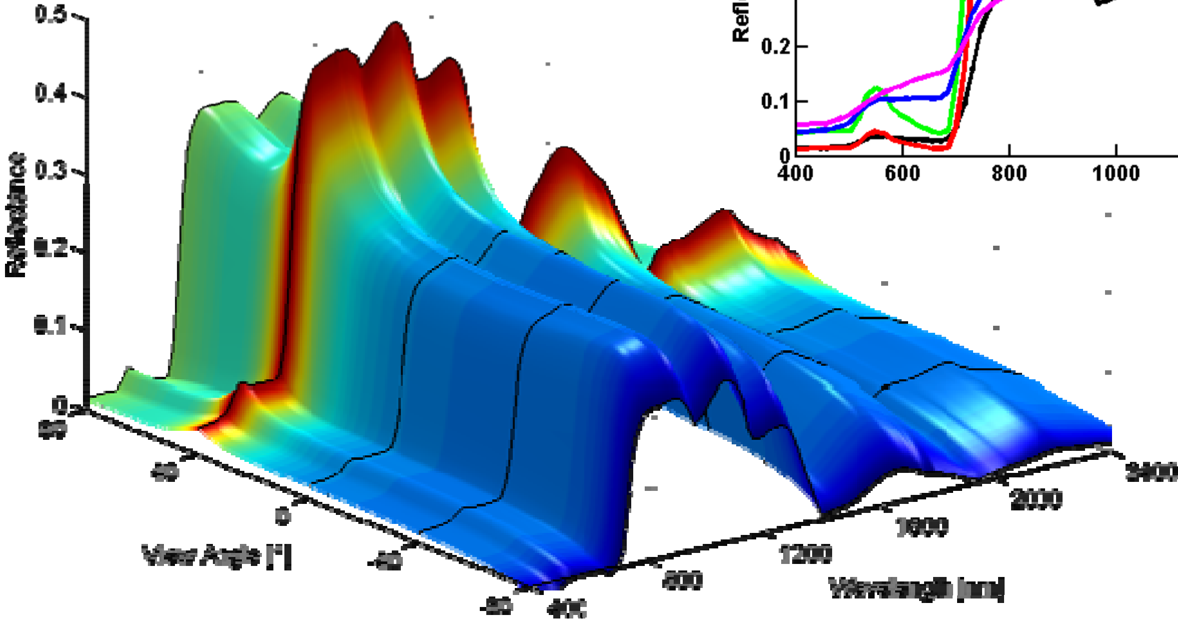


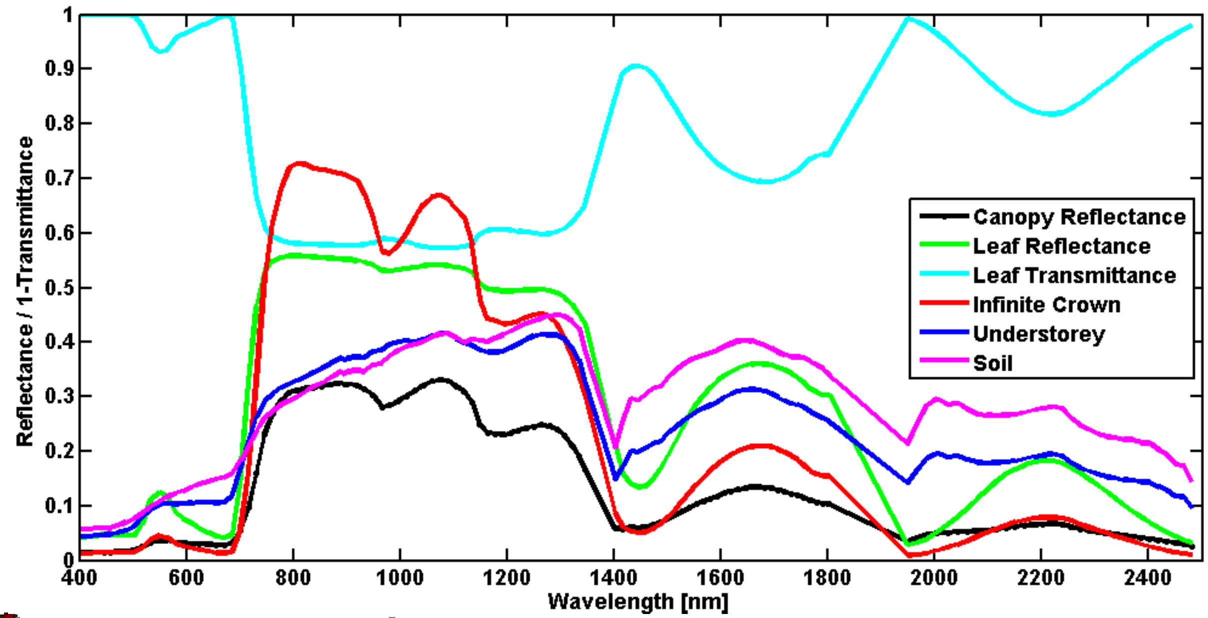


Invertible Forest Reflectance Model

(Atzberger, 2000; Schlerf & Atzberger, 2005)

INFORM:
PROSPECT & SAILH & FLIM





Comparison of Canopy Reflectance models

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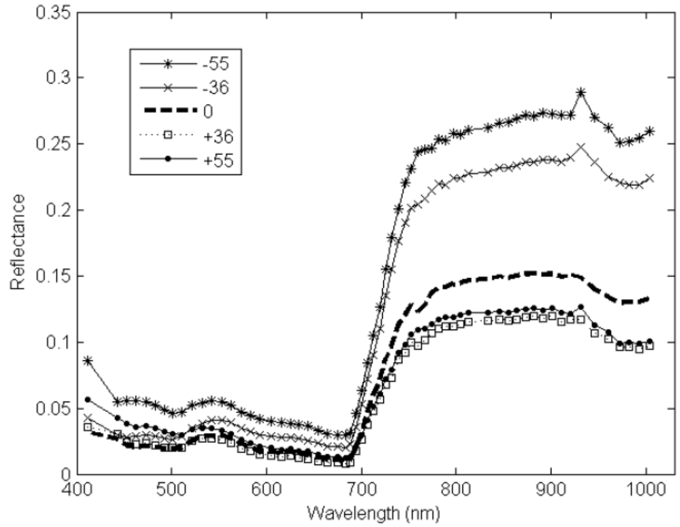
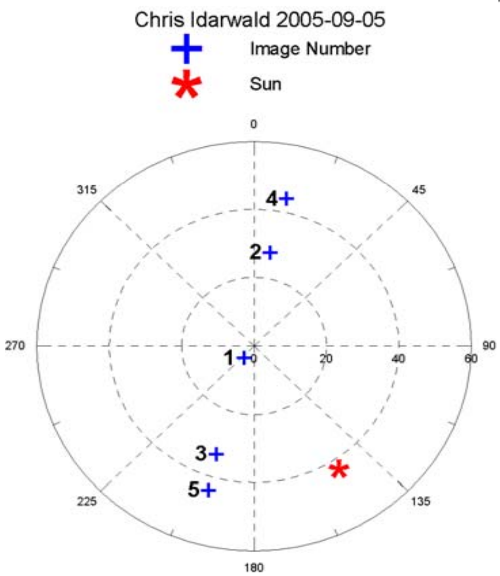
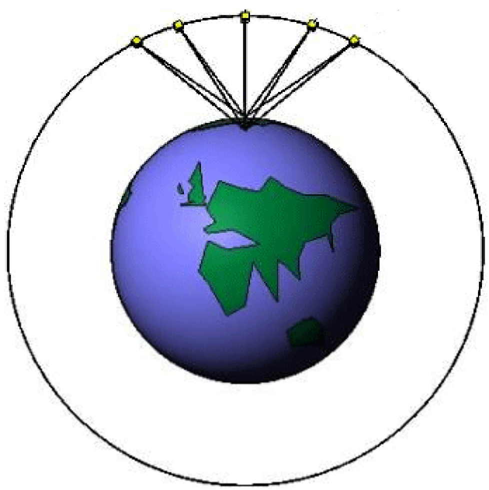
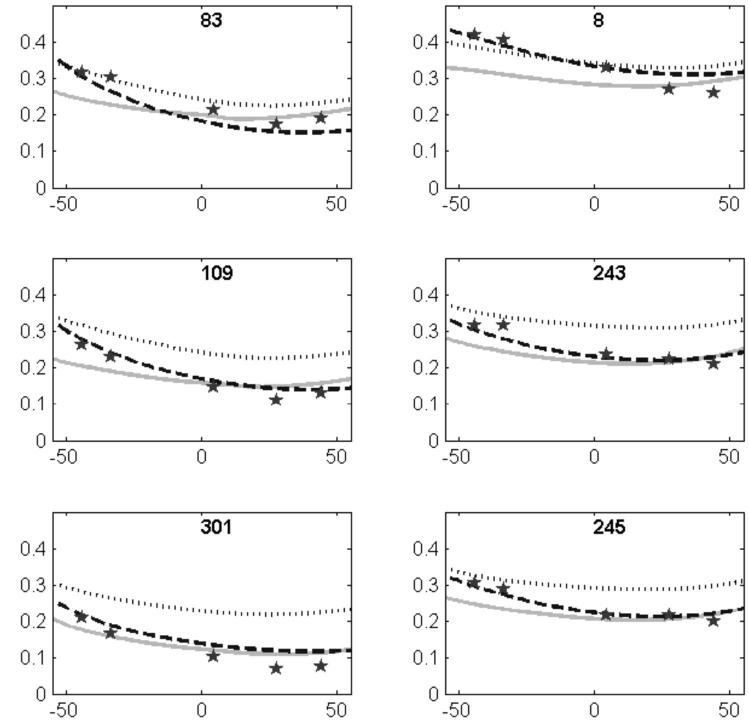








Grey line = FRT, black dashed line = INFORM, black dotted line = SLC, black stars = Chris/PROBA

Comparing Three Canopy Reflectance Models with Hyperspectral Multi-angular Satellite Data
M. Schlerf, W. Verhoef, H. Buddenbaum, J. Hill, C. Atzberger & A. Skidmore (2007)

Forest Growth Models

Universität Trier Remote Sensing Department

ASSESSMENT OF FOREST PRODUCTIVITY USING AN ECOSYSTEM PROCESS MODEL, REMOTELY SENSED LAI MAPS AND FIELD DATA

M. Schlerf[a], H. Buddenbaum[a], M. Vohland[a], W. Werner[b], P.H. Dong[c], J. Hill[a]

a Remote Sensing Department, University of Trier, Behringstrasse, D-54286 Trier, Germany
b Department of Geobotany, University of Trier
c Forest Research Institute Rheinland-Pfalz, D-67705 Trippstadt

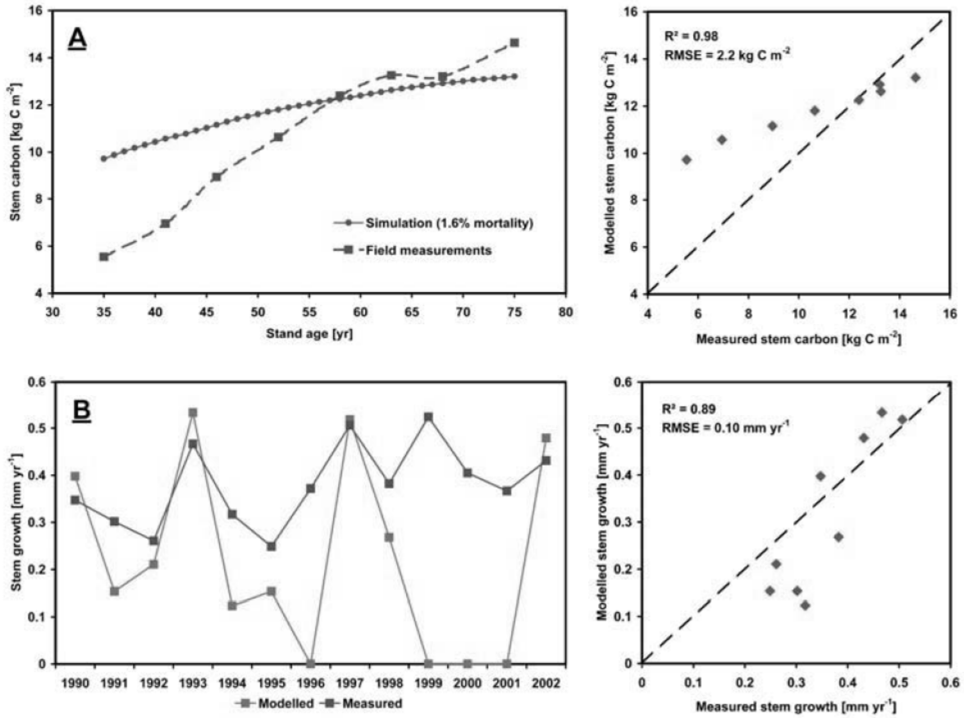
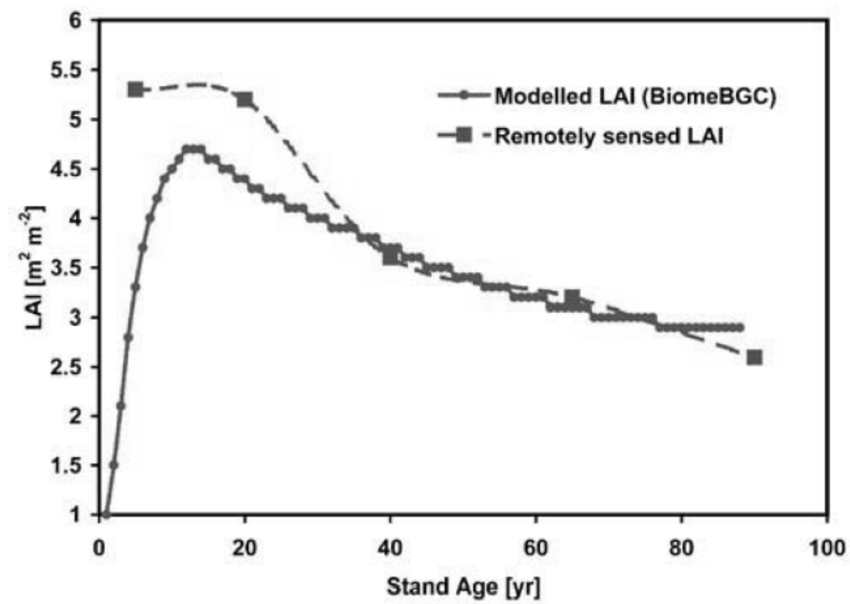


Figure 2: A) Left: Age course of modelled and measured stem carbon, right: scatter plot. B) Left: Age courses of modelled and measured radial stem increment (stem growth), right: scatter plot showing nine of thirteen measurements (four years were left out where modeled values of stem growth were zero).

BiomeBGC



Norway Spruce (picea abies)

Thank you
for your Attention

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