THE USE OF AIRBORNE HYPERSPECTRAL REFLECTANCE DATA TO CHARACTERIZE FOREST SPECIES DISTRIBUTION PATTERNS

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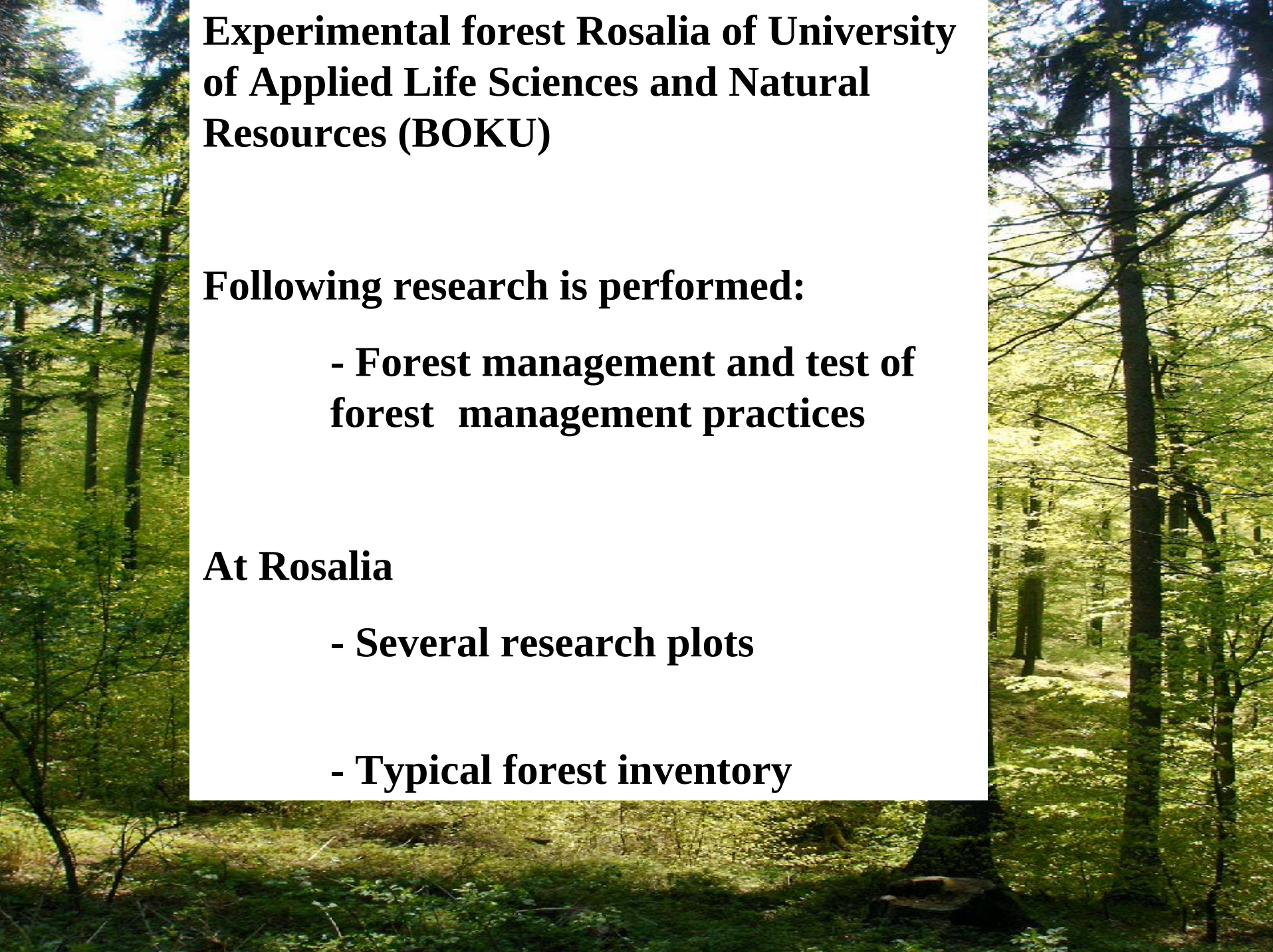
- OVERALL GOAL

Test methods to retrieve forest growth from Remote Sensing information

- AIMS OF THE STUDY

Test potential of Remote Sensing technologies based on airborne hyperspectral data of the experimental forest of BOKU



Experimental forest Rosalia of University of Applied Life Sciences and Natural Resources (BOKU)

Following research is performed:

- **Forest management and test of forest management practices**

At Rosalia

- **Several research plots**

- **Typical forest inventory**

Experimental Forest in the Rosalian Mountains

1000 ha
Elevation: 400 - 900 m
Norway spruce, silver fir, common beech, scots pine (only few)

HYMAP SPECTRAL MEASUREMENTS

Airborne imaging system onboard Do 228 aircraft

(Deutsche Luft und Raumfahrt Gesellschaft, DLR)

Hymap Sensor has 4 spectrometers

128 spectral bands

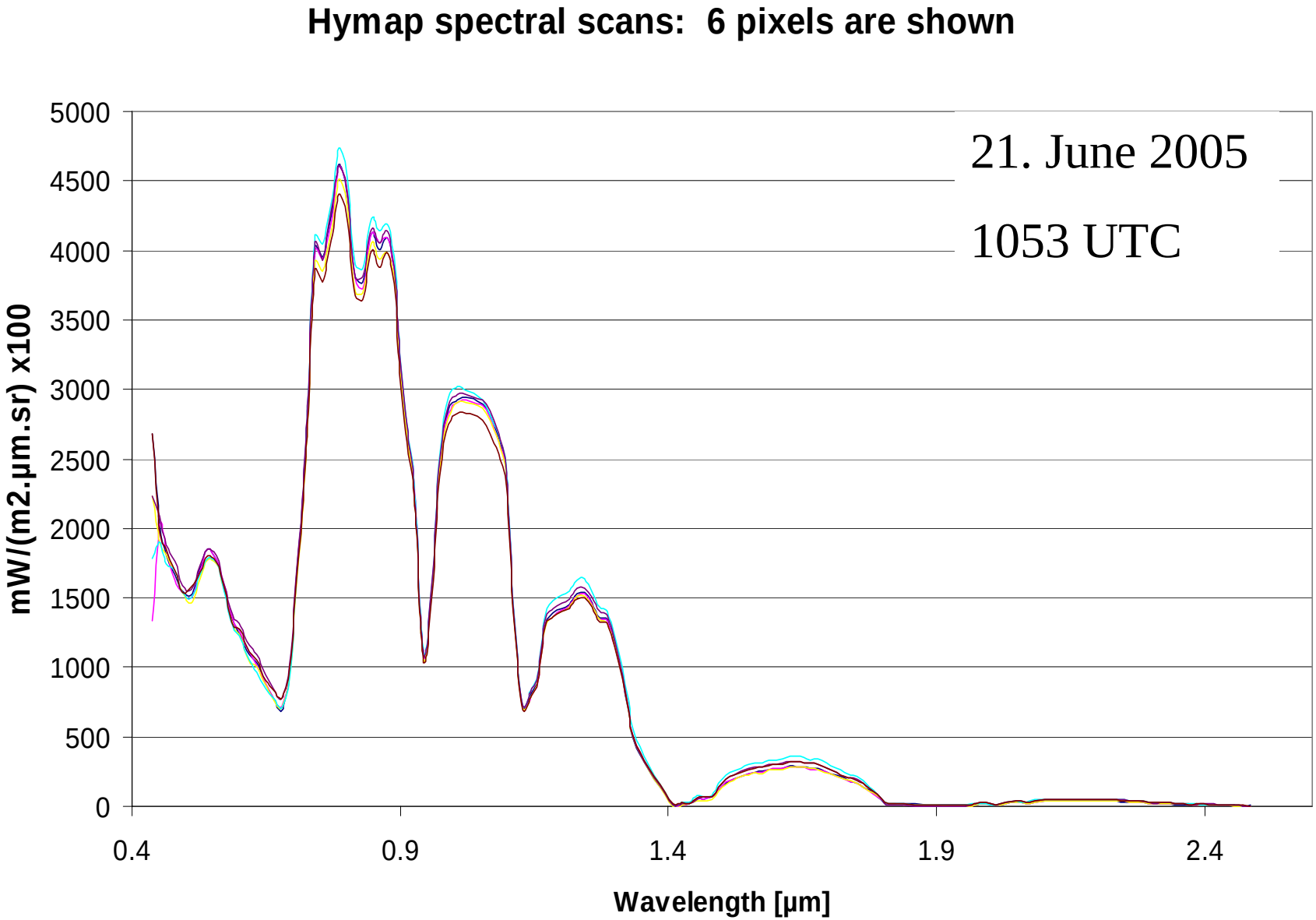
Wavelength range: 400 -2500 nm, bandwidth 15nm

Flight altitude: 1910 m above ground level

Approximately 4 m Pixel resolution

Flight direction 343 °

Angular width 61.3°


Hymap spectral scans: 6 pixels are shown
21. June 2005
1053 UTC
mW/(m2.µm.sr) x100
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.4
0.9
1.4
1.9
2.4
Wavelength [µm]

Pre processing of spectral data

- Atmospheric correction with 6S code.

    - Recalibration function applied to remove spectral artifacts (Moreno et al., 2004)

    - Ground based spectrometer reflectance measurements for calibration check

- Topographic correction (inclination, obstruction of horizon) using digital elevation map with 25 m resolution

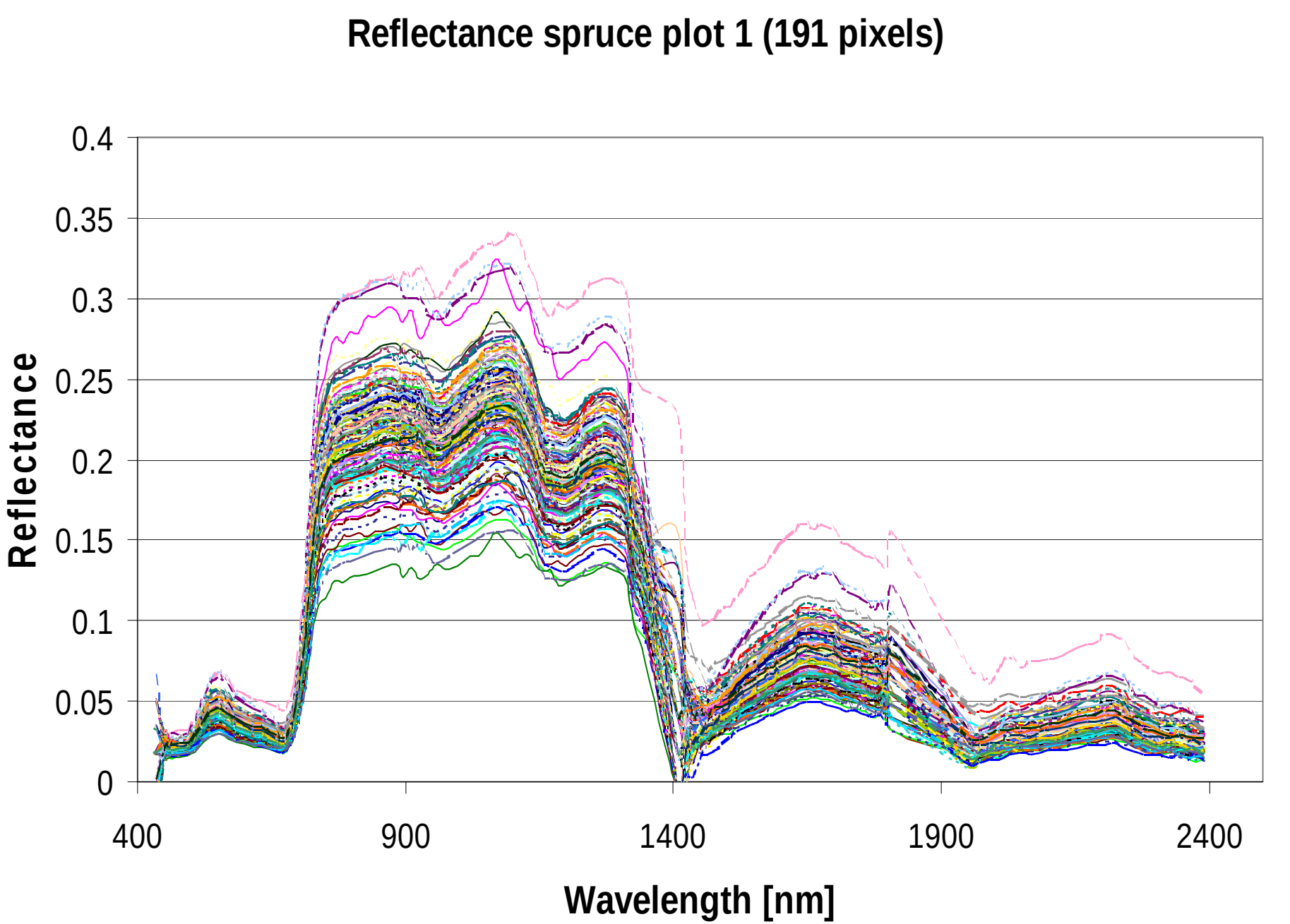
- BRDF taken into account for calculations of indices by using model ACRM (version 07/05) by Kuusk

STRUCTURE

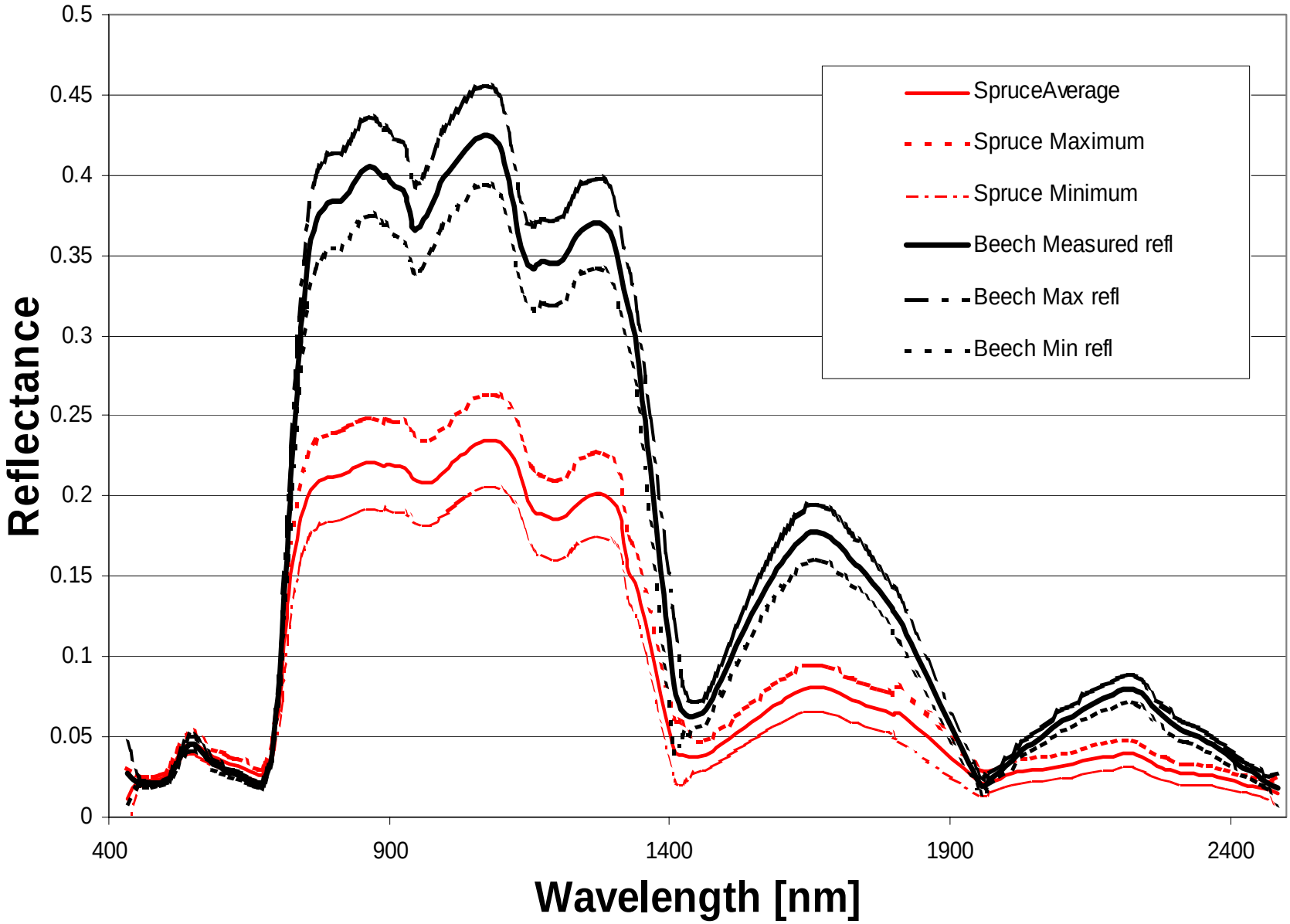
A) First analysis of data

B) Comparison HyMap reflectance with reflectance models

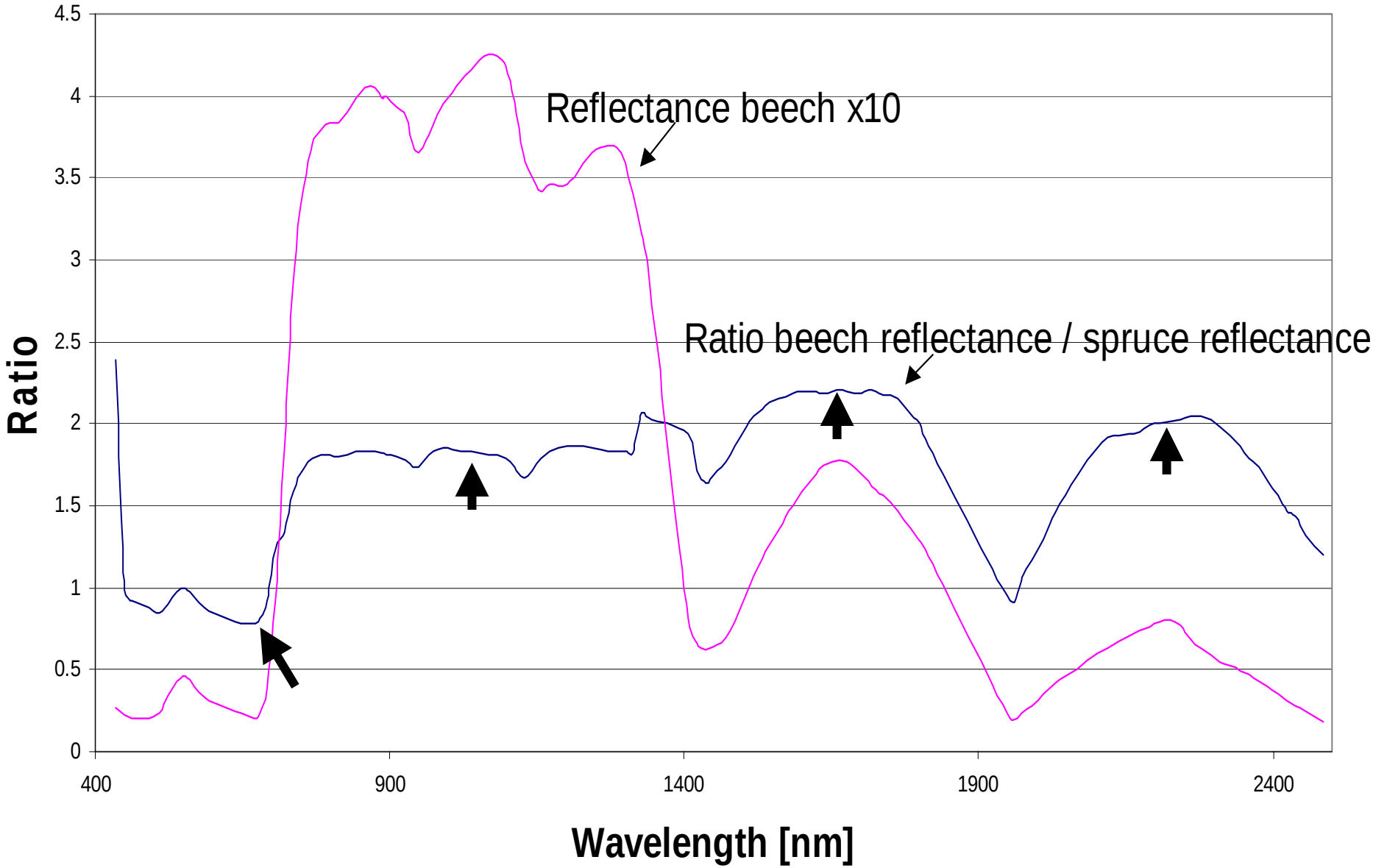
C) Application: investigation of regional influences by using forest reflectance model inversion and well known indices


Reflectance spruce plot 1 (191 pixels)
Reflectance
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
400
900
1400
1900
2400
Wavelength [nm]

Comparison Spruce and Beech reflectance



Ratio Beech(LAI 2.7) / Spruce (LAI 4.5)



STRUCTURE

A) First analysis of data

→ B) Comparison HyMap reflectance with reflectance models

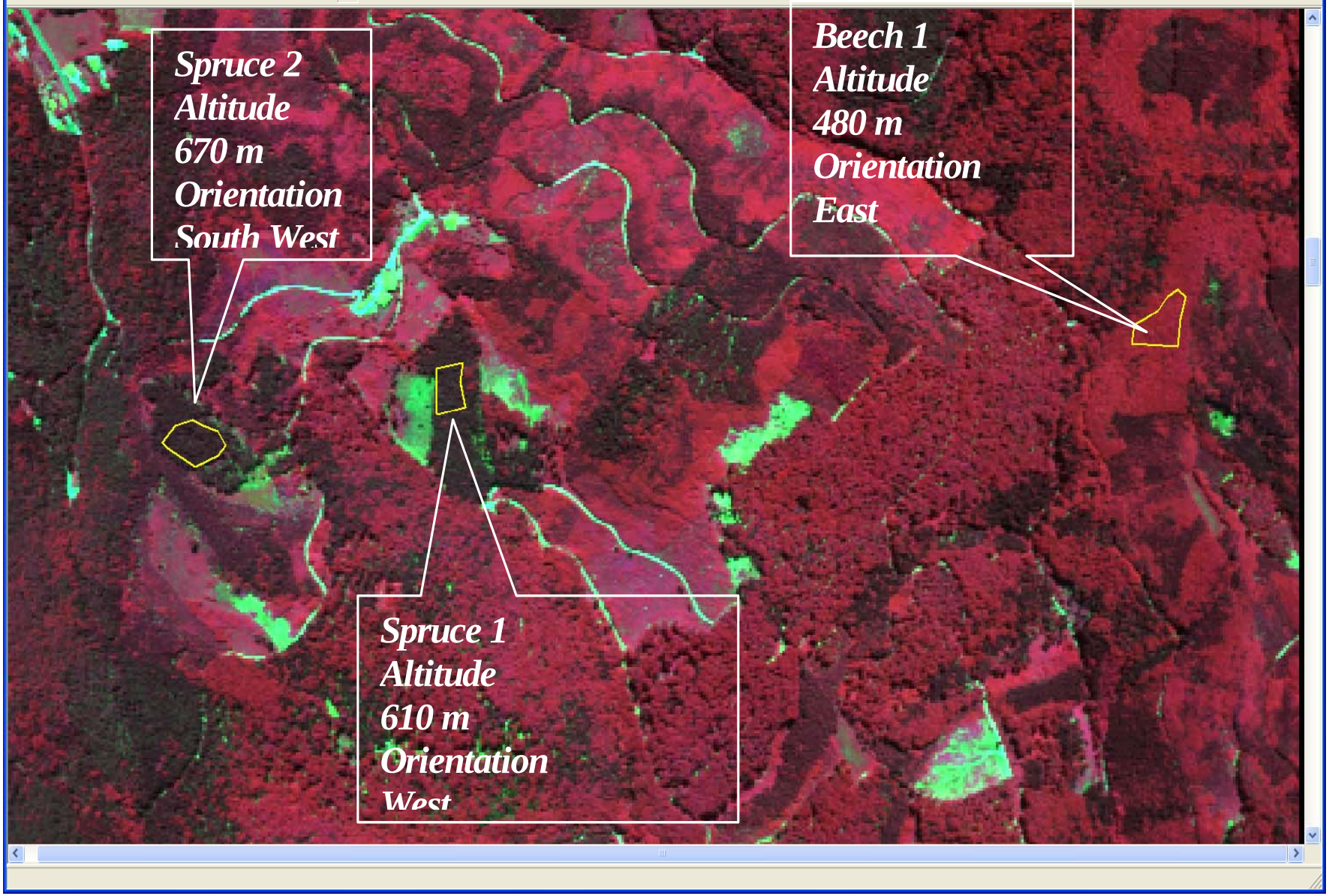
C) Application: investigation of regional influences by using well known indices and radiative transfer model inversion

FOREST REFLECTANCE MODELS USED IN THIS STUDY

Model ACRM (Version July 2005) (Kuusk, 2001)
- directional multispectral homogeneous canopy reflectance (two layer model)
- Input parameters: LAI, leaf incl. angle, leaf size, biochemical parameters of leaves, soil reflectance

Model FRT (Kuusk and Nilson, 2002)
- directional multispectral homogeneous canopy reflectance (two layer model)
- Input parameters: LAI, leaf incl. angle, leaf size, biochemical parameters of leaves, soil reflectance, **exact dimension of trees (height, crown, trunk), trunk + branch reflectance**

For FRT and ACRM:
- Wavelength range:400-2400/2500 nm / 1 nm resolution
- Work for any view and sun direction
- Work in forward and inverse mode



Hymap: Bildflug vienna4, 21.6.2005, Bandkombination 24/17/8

Selected reference forest plots	Beech 480m /E 20° incl.	Spruce 1 610m/W 18° incl	Spruce 2 670m/SW 16° incl
Age [years]	65	120	130
LAI	2.7 ± 0.5	4.9± 0.5	4.6± 0.5
Height [m]/ Crown dim.[m]	25 / --	25/ (2.7-5.9)	30/ (4.5-7.2)
Canop. Closure [%] Stand density /m²	100 / 0.054	60 / 0.037	90 / 0.062
Ground vegetation	none	none	none

Following model input parameters were estimated (from literature)

- Soil reflectance

- Leaf inclination /eccentricity

- Bark and trunk reflection

- Total dry leaf weight / Leaf weight per area

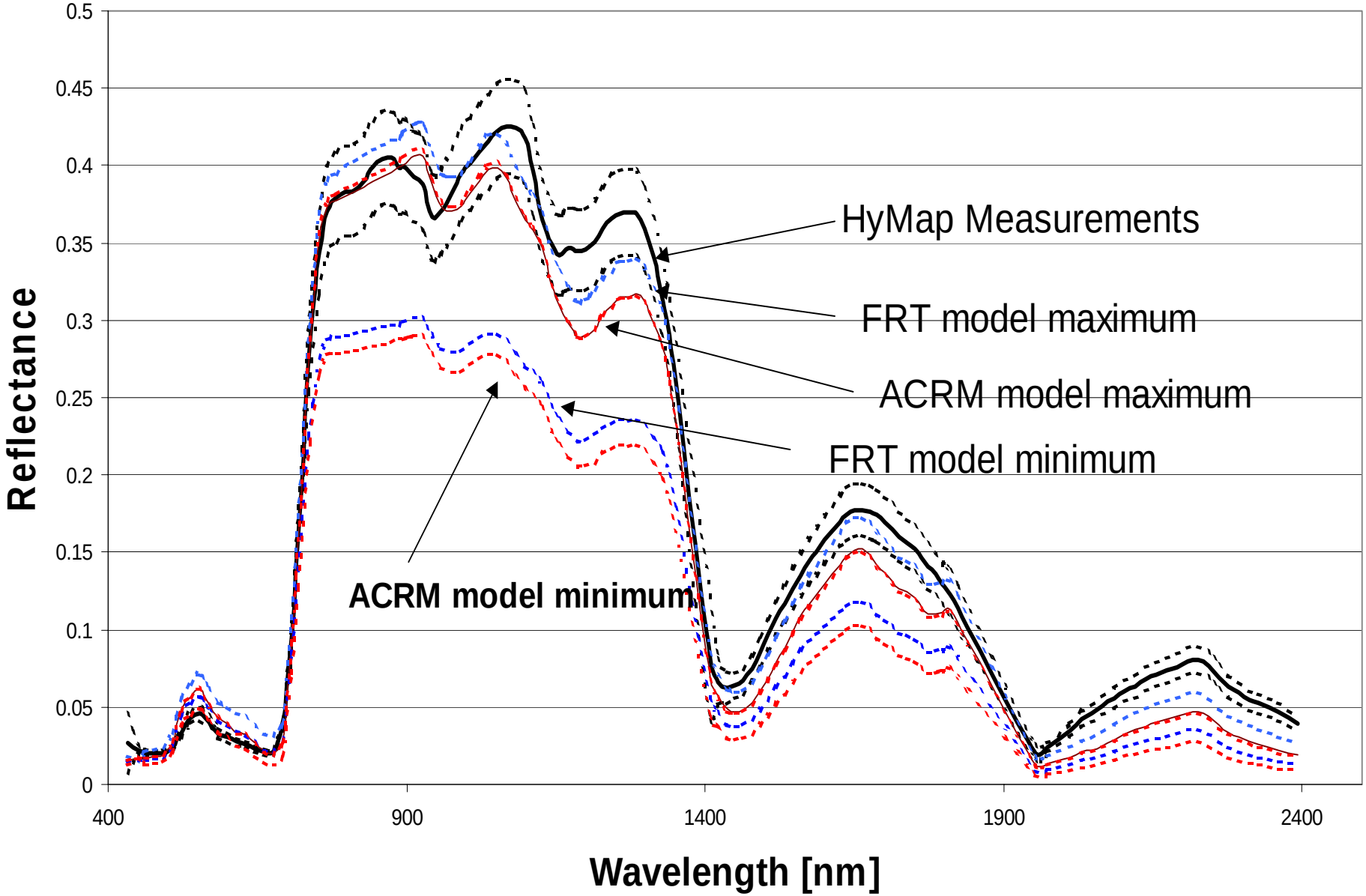
- BAI/LAI ratio

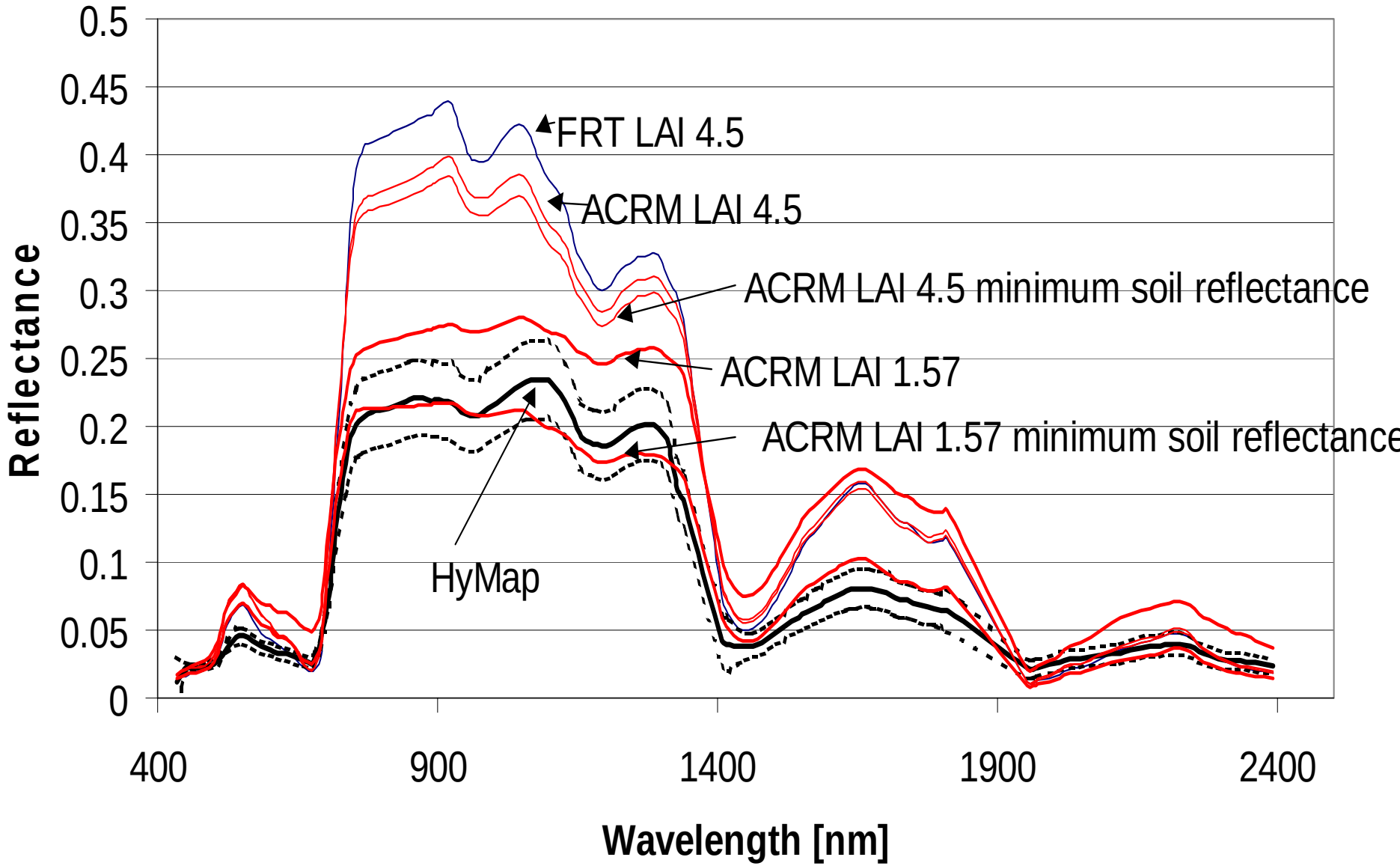
- Shoot shading coefficient

- Markov parameter

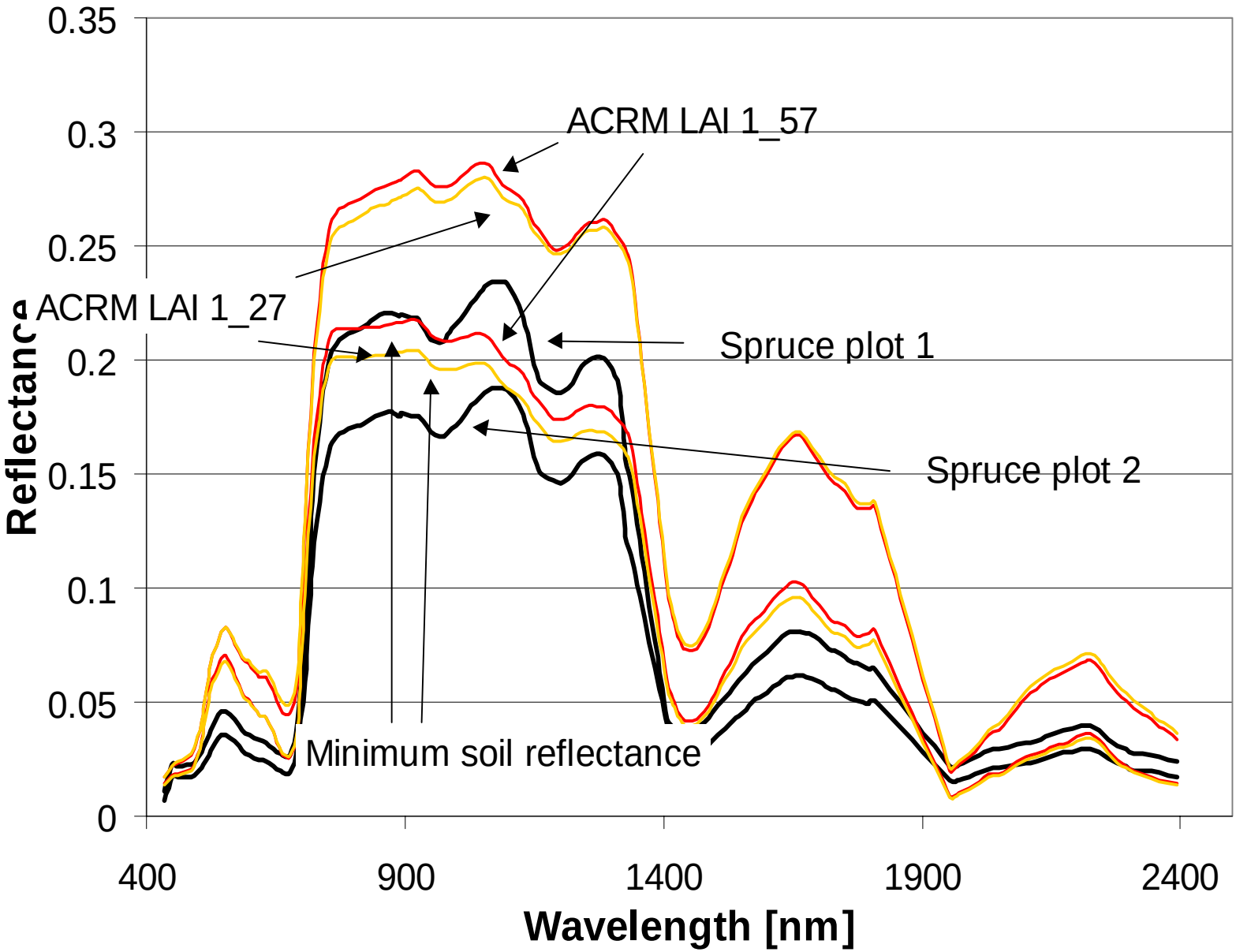
- Percentage of constituents in leaves (dry matter, water content, chlorophyll, pigments)

Reflectance beech plot: comparison with models




Reflectance Spruce plot 1 comparison with models
Reflectance
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
400
900
1400
1900
2400
Wavelength [nm]
FRT LAI 4.5
ACRM LAI 4.5
ACRM LAI 4.5 minimum soil reflectance
ACRM LAI 1.57
ACRM LAI 1.57 minimum soil reflectance
HyMap

Spruce plot 1 and 2 comparison with ACRM model

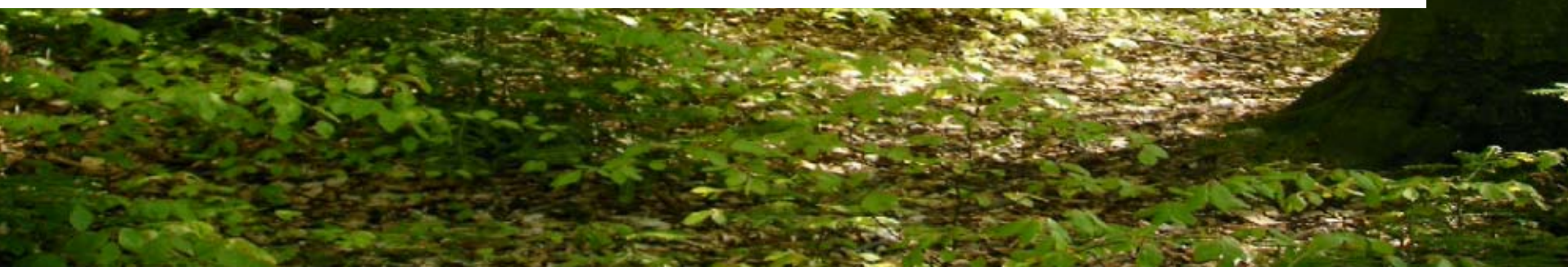


STRUCTURE

A) First analysis of data

B) Comparison HyMap reflectance with reflectance models

→ C) Application: investigation of regional influences by using forest reflectance model inversion and well known indices



Forest growth is driven by

- Climate
- Water
- Energy
- Nutrition

These factors influence carbon cycle and forest growth

The limiting factors are key driver

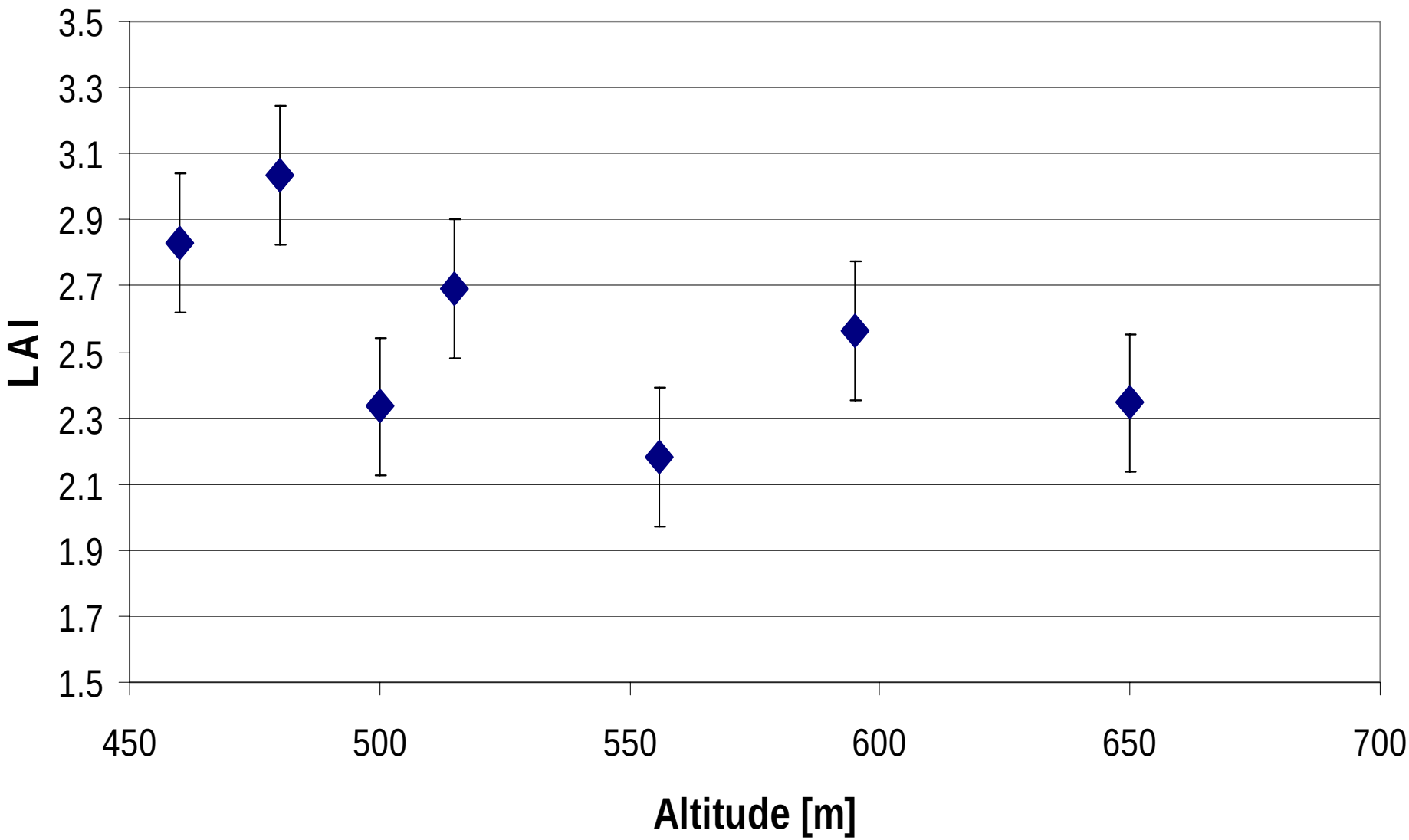
e.g. water is limiting factor for vegetation growth

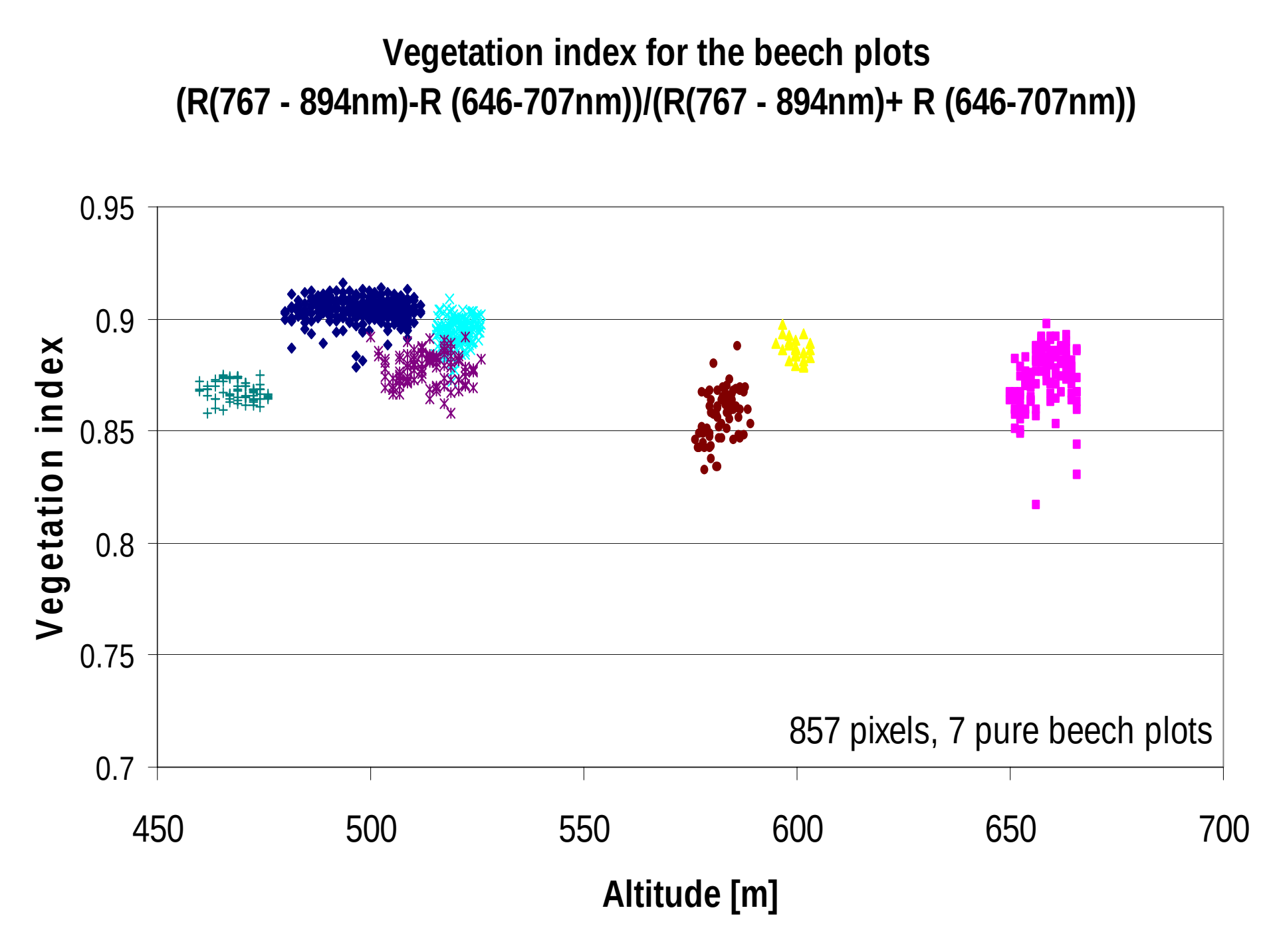
Regional influences were investigated using 7 pure beech plots and 7 pure spruce plots

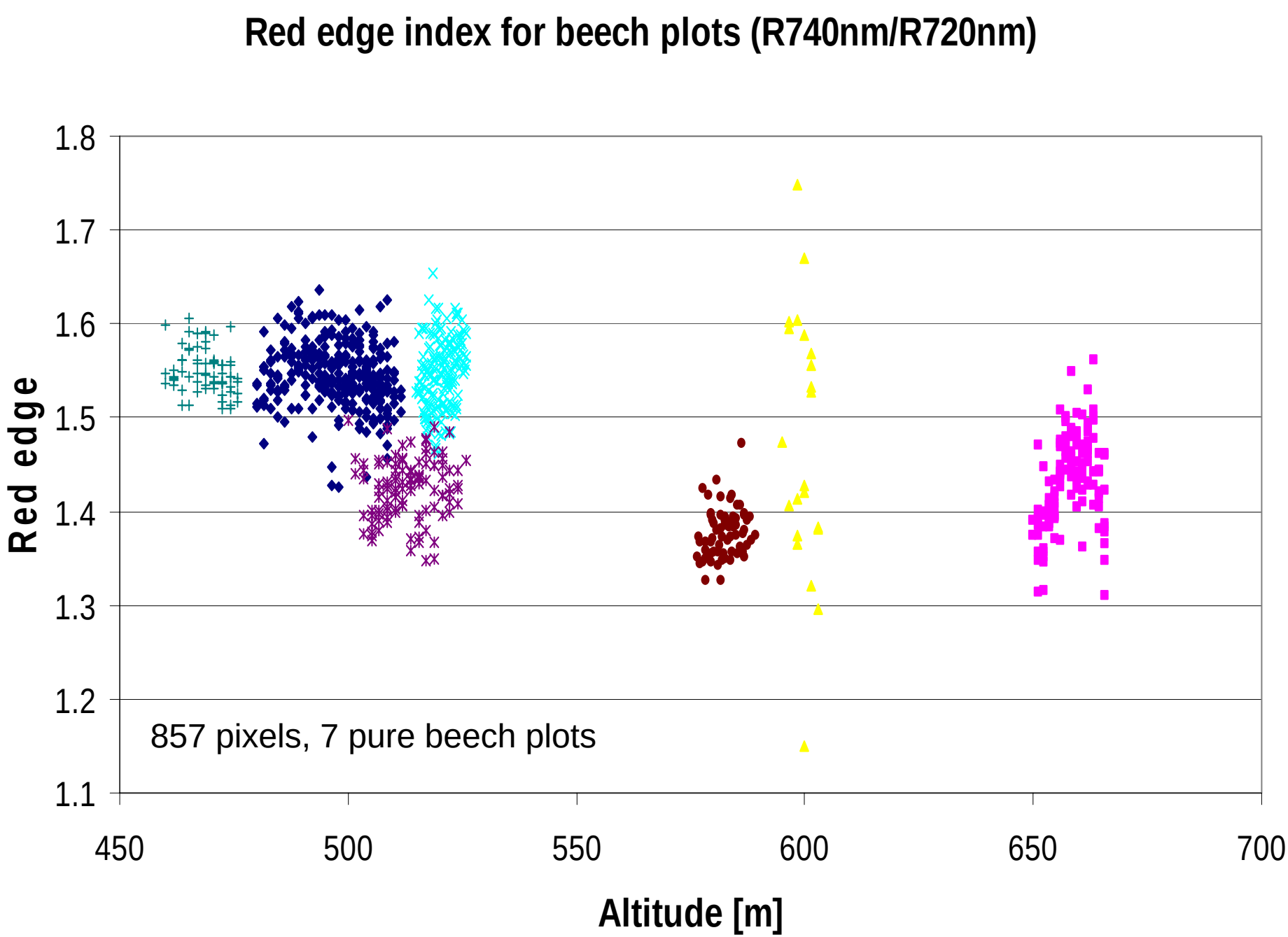
Indices used in this study:

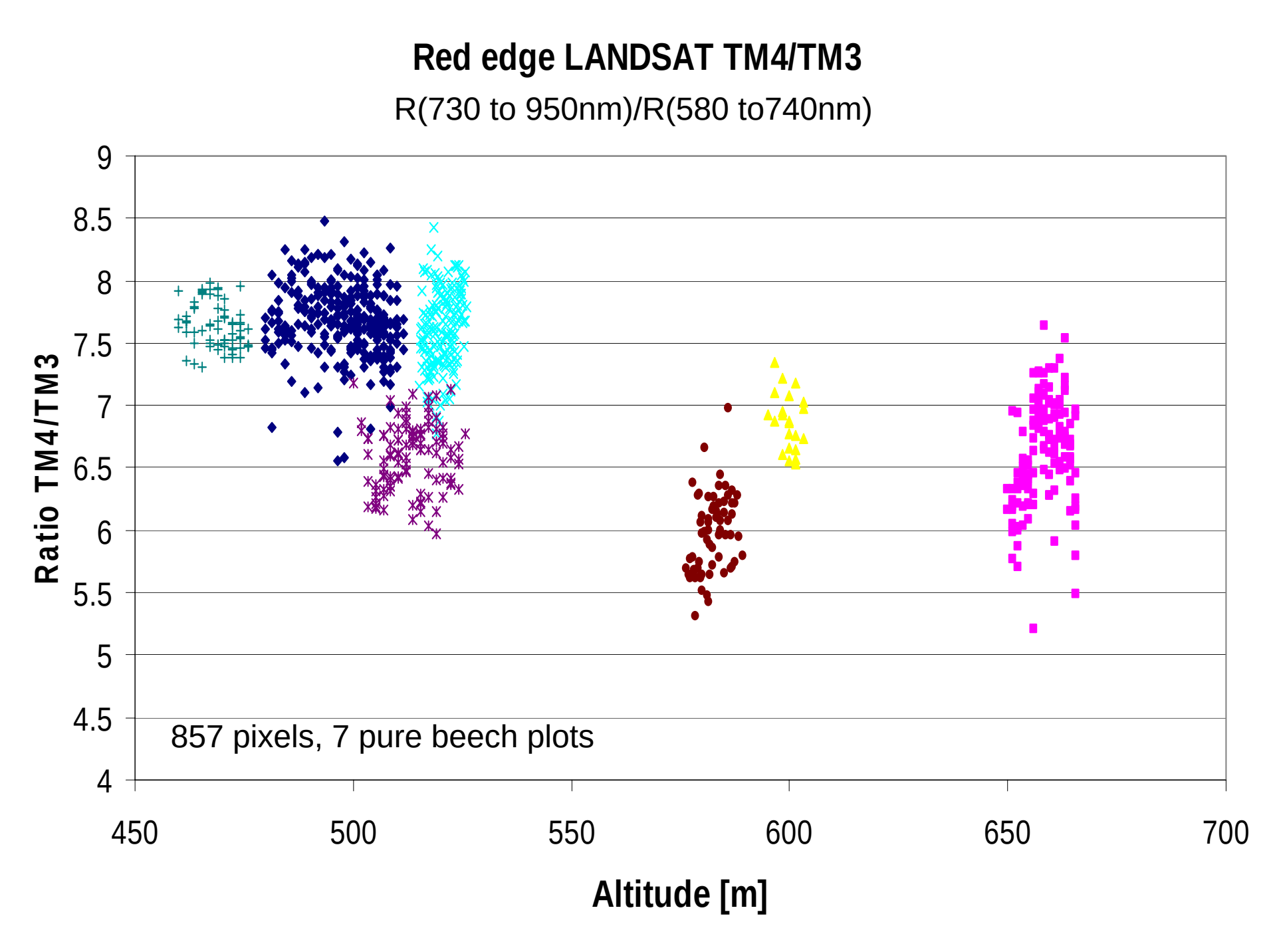
- LAI model inverted (ACRM model)
- Vegetation index (1)
- Red edge index (stress indicator of vegetation) (2;3)
- LANDSAT Red edge (TM4/TM3)
- Yellowness index (chlorosis in stressed leaves (4;5))
- PRI (Photosynthetic radiation use efficiency (4;6;7;8))

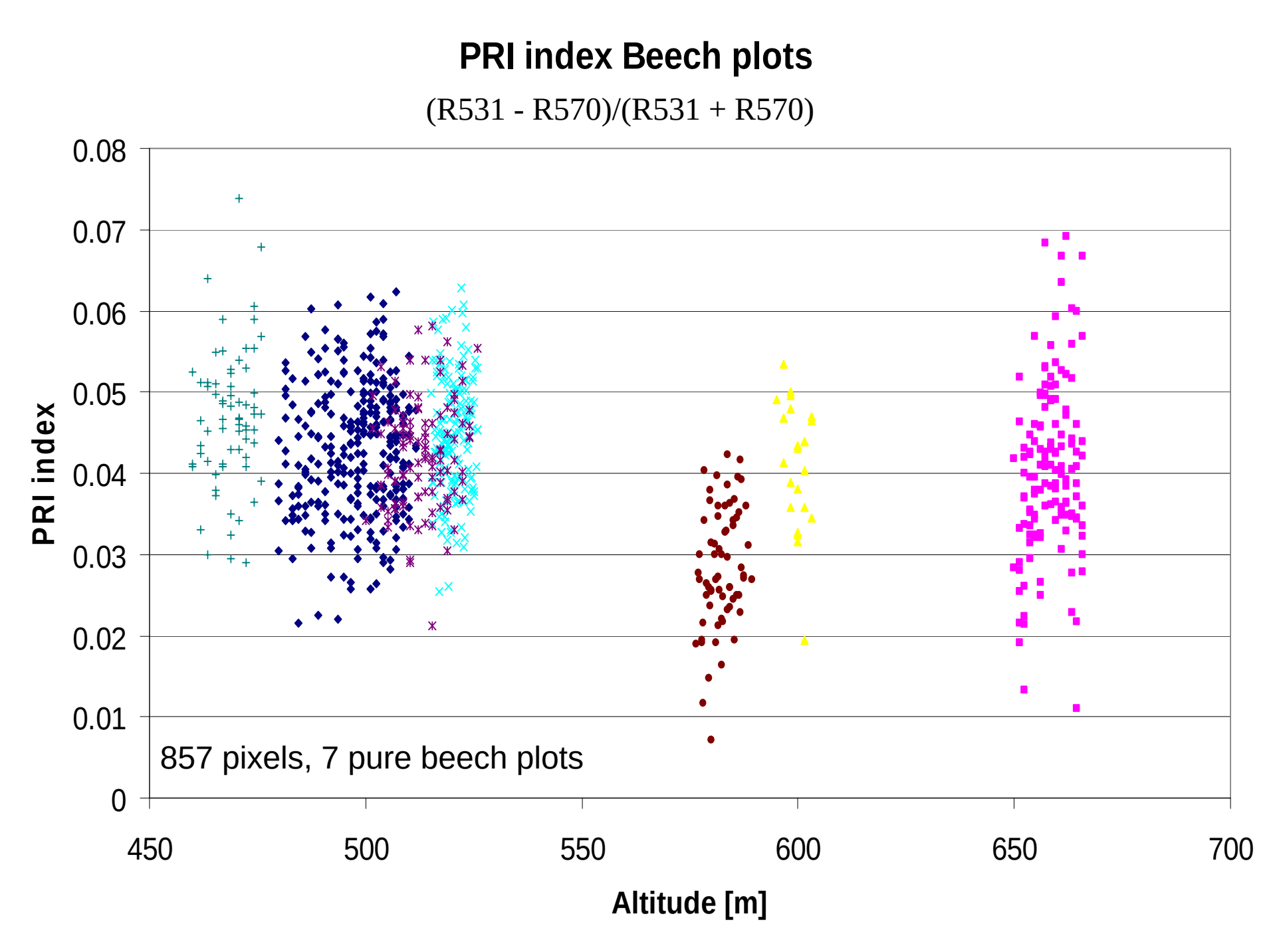
1= Kappas (1993), 2= Vogelmann (1993), 3= Zarco Tejada(1999), 4= Richardson et al.(2003),5= Adams et al. (1999), 6= Gamon et al.(1997), 7= Penuelas et al. (1995), 8= Filella et al. (1996)

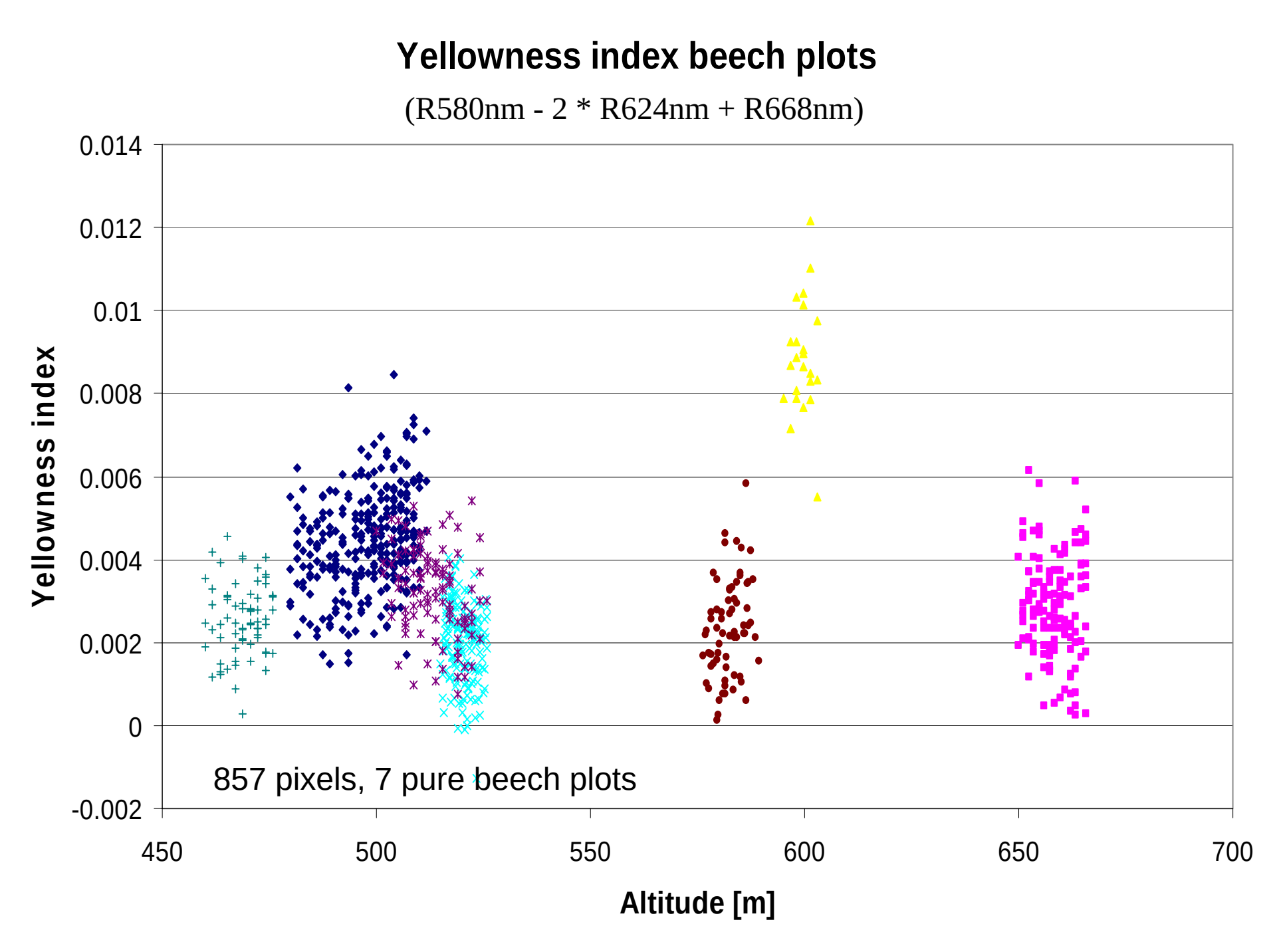

Model Retrieved LAI (ACRM)
for 7 pure beech plots
LAI
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
450
500
550
600
650
700
Altitude [m]


Vegetation index for the beech plots
(R(767 - 894nm)-R (646-707nm))/(R(767 - 894nm)+ R (646-707nm))
Vegetation index
0.95
0.9
0.85
0.8
0.75
0.7
857 pixels, 7 pure beech plots
450
500
550
600
650
700
Altitude [m]

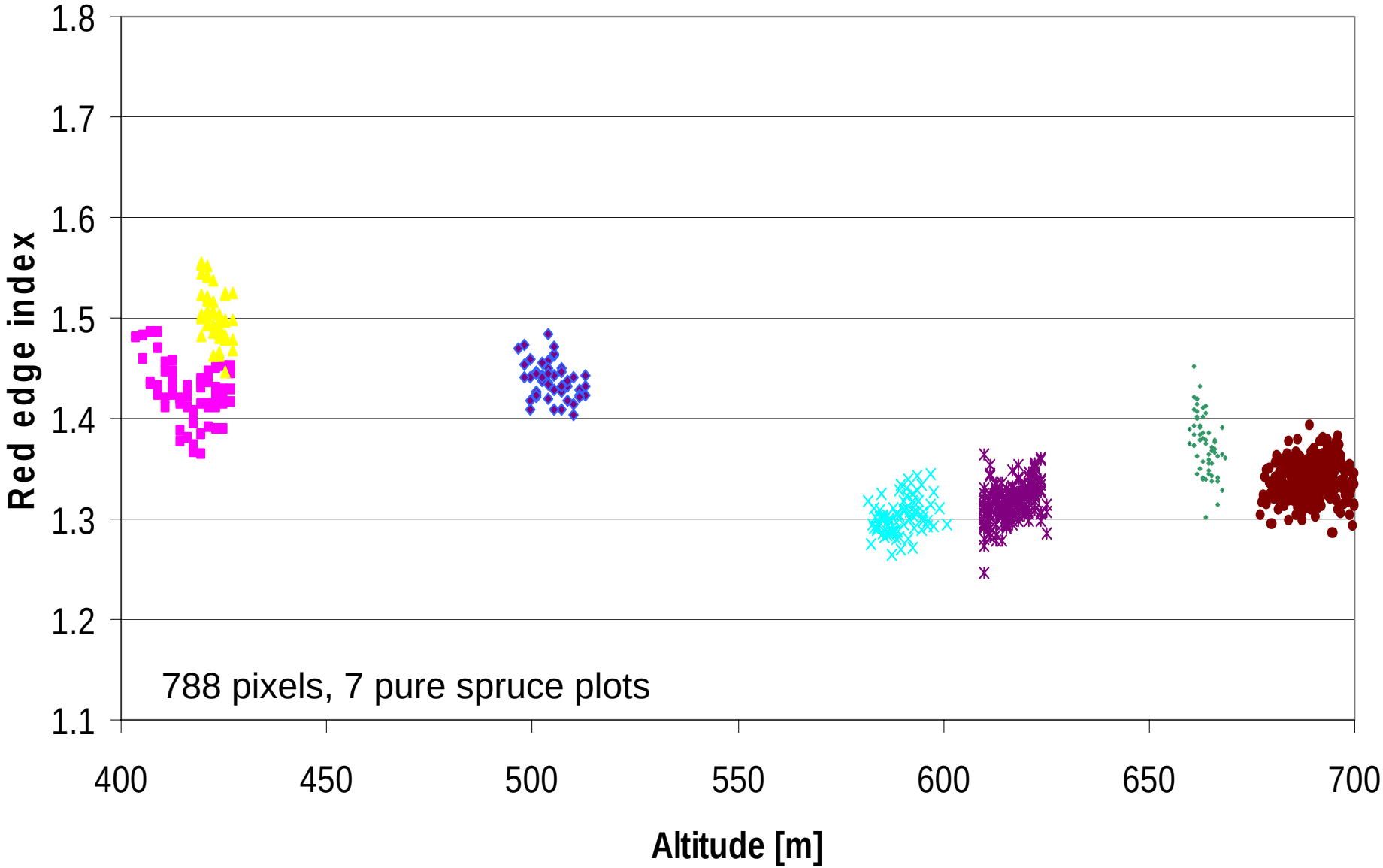

Red edge index for beech plots (R740nm/R720nm)
Red edge
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
857 pixels, 7 pure beech plots
450
500
550
600
650
700
Altitude [m]

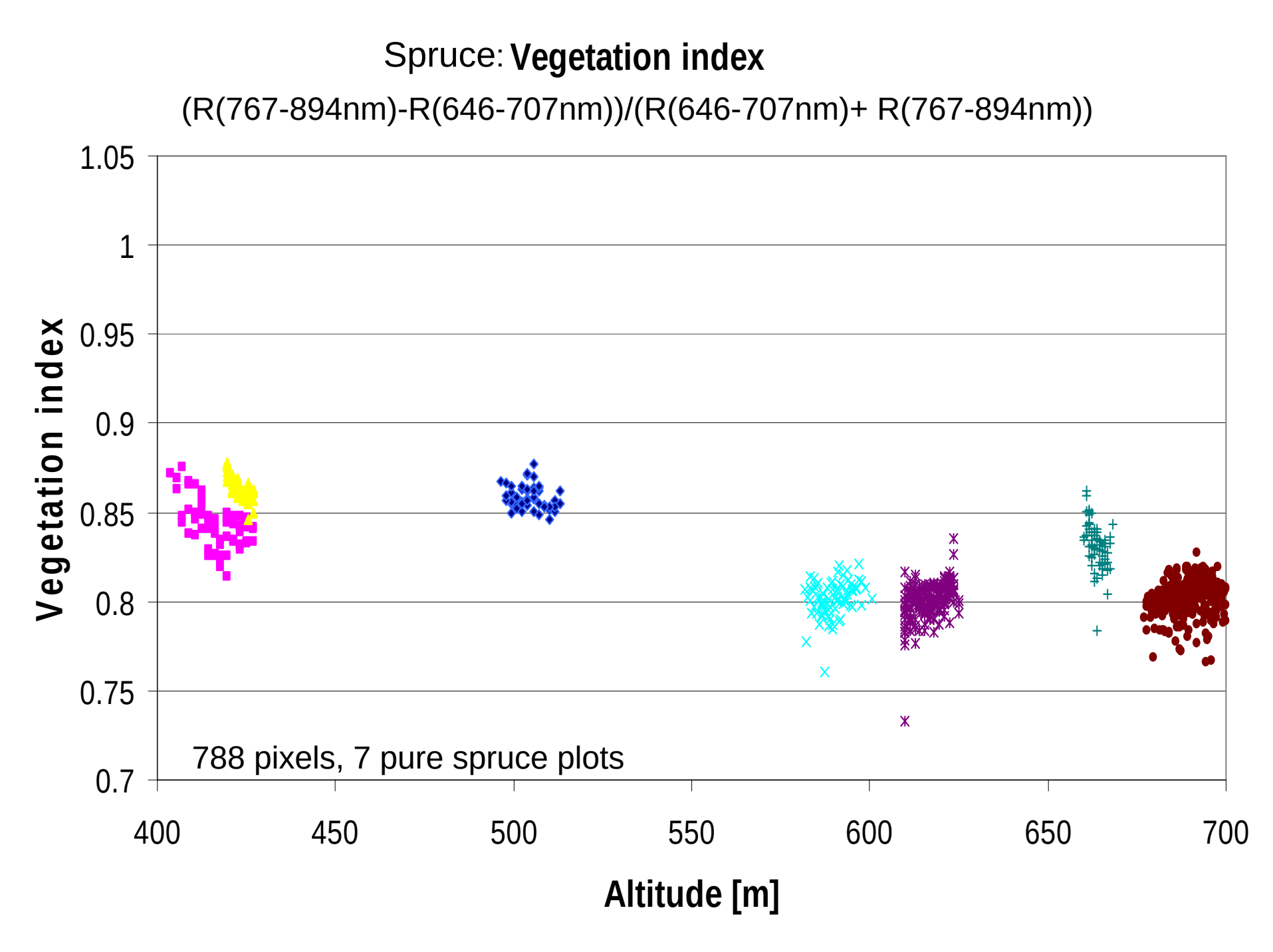

Red edge LANDSAT TM4/TM3
R(730 to 950nm)/R(580 to740nm)
Ratio TM4/TM3
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
857 pixels, 7 pure beech plots
450
500
550
600
650
700
Altitude [m]


PRI index Beech plots
(R531 - R570)/(R531 + R570)
PRI index
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
857 pixels, 7 pure beech plots
450
500
550
600
650
700
Altitude [m]


Yellowness index beech plots
(R580nm - 2 * R624nm + R668nm)
Yellowness index
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
857 pixels, 7 pure beech plots
450
500
550
600
650
700
Altitude [m]

Red edge Spruce plots (R740nm/R720nm)




Spruce: Vegetation index
(R(767-894nm)-R(646-707nm))/(R(646-707nm)+ R(767-894nm))
Vegetation index
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
788 pixels, 7 pure spruce plots
400
450
500
550
600
650
700
Altitude [m]

	Correlation	Change/100m rough estimation
LAI	-0.59	- 0.3
BEECH Red edge 740/720	-0.56	- 0.1 ± 0.05
BEECH Red edge LANDSAT TM4/TM3.	-0.60	- 0.75
SPRUCE Red edge 740/720	-0.68	- 0.1 ± 0.05
SPRUCE Vegetation index	-0.71	- 0.02
BEECH Vegetation index	-0.43	- 0.002
Yellowness	-0.08	
PRI	-0.21	

CONCLUSIONS

A) Analysis of data:

- Beech and spruce may be easily distinguished by comparing their spectral reflectance

- For one homogeneous plot (pure beech or pure spruce) maximum deviation of reflectance amounts to up to 50%

B) Comparison modeled and measured reflectance

- No agreement for spruce

- Model and measurements agree for beech if uncertainties in measurements and input parameters are taken into account

- Soil reflectance has a large influence especially if LAI is lower than 3.

CONCLUSIONS (2)

C) Studies of regional influences

- Analysis suggest dependence of some indices on altitude

    - Decrease of LAI with altitude

    - Decrease of vegetation index (less dense vegetation)

    - Decrease of red edge index with altitude (increase of stress with altitude)

THANK YOU

FOR

YOUR ATTENTION!!

These investigations were performed within the scope of the project DROSMON supported by the Austrian Science Foundation (FWF)