VAlidation of Land European Remote sensing Instruments

I. Ground validation activities and processing within VALERI

Philippe Rossello, Frédéric Baret

CEOS/LPV-VALERI workshop

Davos, 15th March 2007

Objectives

The objectives are to provide high spatial resolution maps of biophysical variables (LAI, fAPAR, fCover) estimated from ground measurements to validate products derived from satellite observations.

For this purpose, the VALERI project offers:

- a methodological framework designed for the derivation of the high spatial resolution maps;
- a pool of instrumentation and tools for ground measurements and processing;
- a network of sites distributed over the Earth’s surface;
- a database of processed and available high spatial resolution maps.

Background

VALERI started in 2000
2000/2003: methodological developments
2004: availability of Can-Eye
2004/2007: enlargment of participants, new Can-Eye tools, improvement of the data processing sequence, available processed data…

Funding agency
Centre National d'Études Spatiales (CNES), Toulouse (France), through Pôle d'Observation des Surfaces continentales par TELédétection (POSTEL)

Funding: 50 kEuros

Results for validation
MODIS, MERIS, CYCLOPES…

Integration in CEOS with MODLAND, BigFoot, CCRS…

International collaborations
Argentina, Australia, Belgium, Benin, Bolivia, Canada, Chile, China, England, Estonia, Finland, France, Germany, Indonesia, Mali, Mexico, Morocco, Niger, Romania, Spain

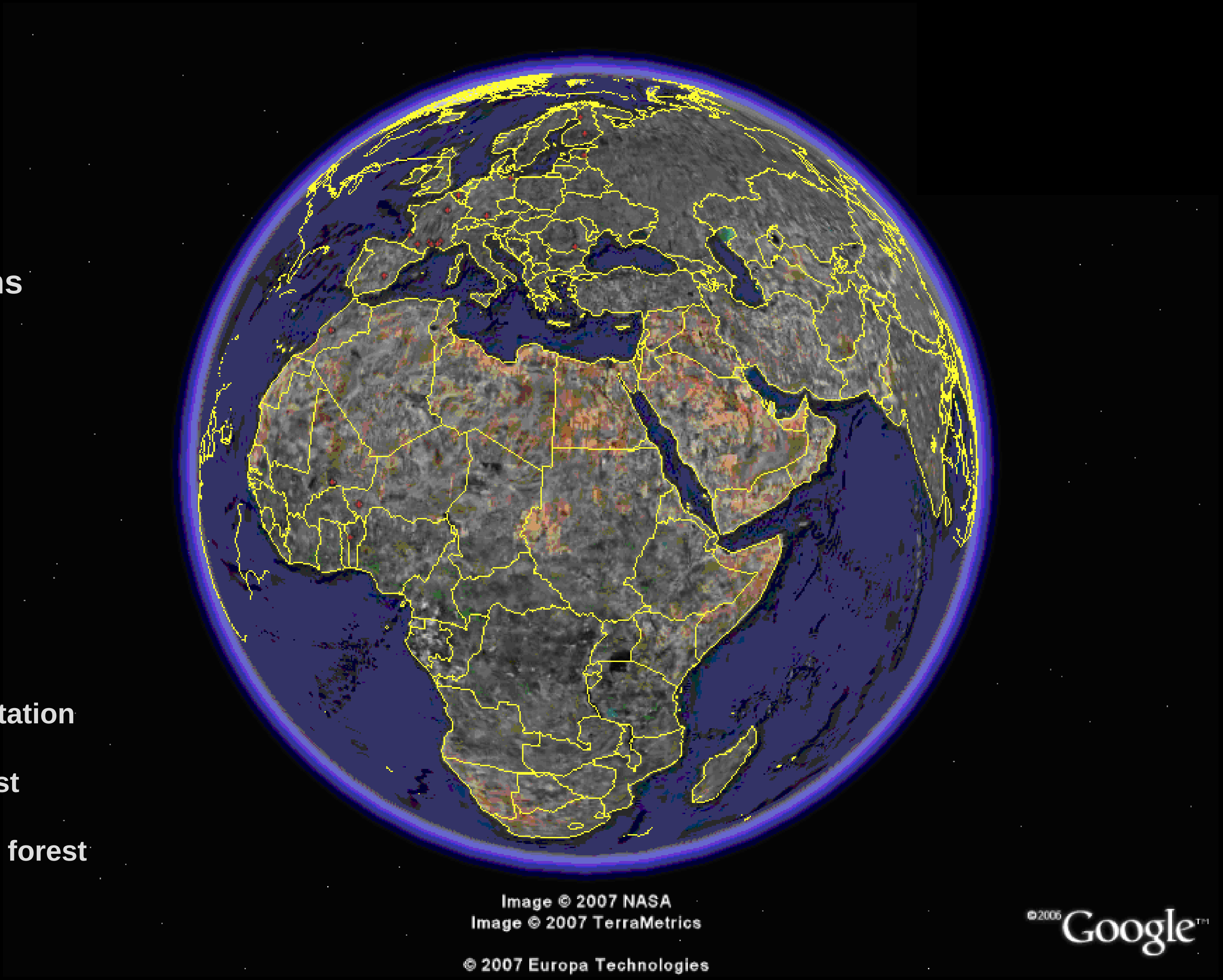
International network of sites

5 continents

21 countries

34 sites

51 campaigns



Landcover

crops
grassland
pasture
forest
mixed forest
tropical forest
plam tree plantation
boreal forest
broadleaf forest
pine forest
mediterranean forest
shrubs

Status of campaigns processing

- 2000: 1/4 campaign processed
- 2001: 4/13 campaigns processed
- 2002: 10/12 campaigns processed
- 2003: 8/8 campaigns processed
- 2004: 3/7 campaigns processed
- 2005: 3/5 campaigns processed
- 2006: 0/3 campaign processed

in total: 29 campaigns processed

About 2 weeks to process one campaign.

List of processed campaigns (1/2)

Site	Country	Landcover	Campaign date	Lat	Lon
Aek Loba	Indonesia	palm tree plantation	2001/05	2°37'51.77"N	99°34'33.83" E
Les Alpilles 1	France	crops	2001/03	43°48'26.37"N	4°44'33.33" E
Les Alpilles 2			2002/07	43°48'37.26"N	4°42'52.6" E
Barrax	Spain	cropland	2003/07	39°4'22.25"N	2°6'14.22" W
Concepción	Chile	mixed forest	2003/01	37°28'2.18"S	73°28'13.38" W
Counami	French Guiana	tropical forest	2002/10	5°20'36.46"N	53°14'12.58" W
Demmin	Germany	crops	2004/06	53°53'31.73"N	13°12'25.92"E
Fundulea	Romania	crops	2001/03	44°24'20.06"N	26°35'6.44" E
			2002/05		
			2003/05		
Gilching	Germany	crops and forest	2002/07	48°4'54.68"N	11°19'13.75" E
Haouz	Morocco	cropland	2003/03	31°39'33.28"N	7°36'1.05" W
Hirsikangas	Finland	forest	2003/08	62°38'38.03"N	27°0'41.15" E
			2005/06	62°38'37.892"N	27°0'41.761"E
Järvselja	Estonia	boreal forest	2002/06	58°17'57.96"N	27°15'36.79" E
			2003/07		
Laprida	Argentina	grassland	2001/11	36°59'25.56"S	60°33'9.61" W
			2002/10	36°59'25.34"S	60°33'9.33" W
Larose	Canada	boreal forest	2003/08	45°22'49.67"N	75°13'1.2" W
Larzac	France	grassland	2002/07	43°56'15.03"N	3°7'22.62" E
Nezer	France	pine forest	2002/04	44°34'4.91"N	1°2'17.69" W
Romilly-sur-Seine	France	cropland	2000/06	48°26'35.37"N	3°46'19.16" E
Rovaniemi	Finland	forest	2004/06	66°27'20.23"N	25°21'5.08" E
			2005/06		
Sonian forest	Belgium	forest	2004/07	50°46'5.34"N	4°24'39.89"E
Sud-Ouest	France	crops	2002/07	43°30'22.67"N	1°14'15.06" E
Turco	Bolivia	shrubs	2002/08	18°14'22.03"S	68°11'35.97" W
			2003/04		
Wankama	Niger	grassland	2005/06	13°38'42"N	2°38'07" E

List of processed campaigns (2/2)

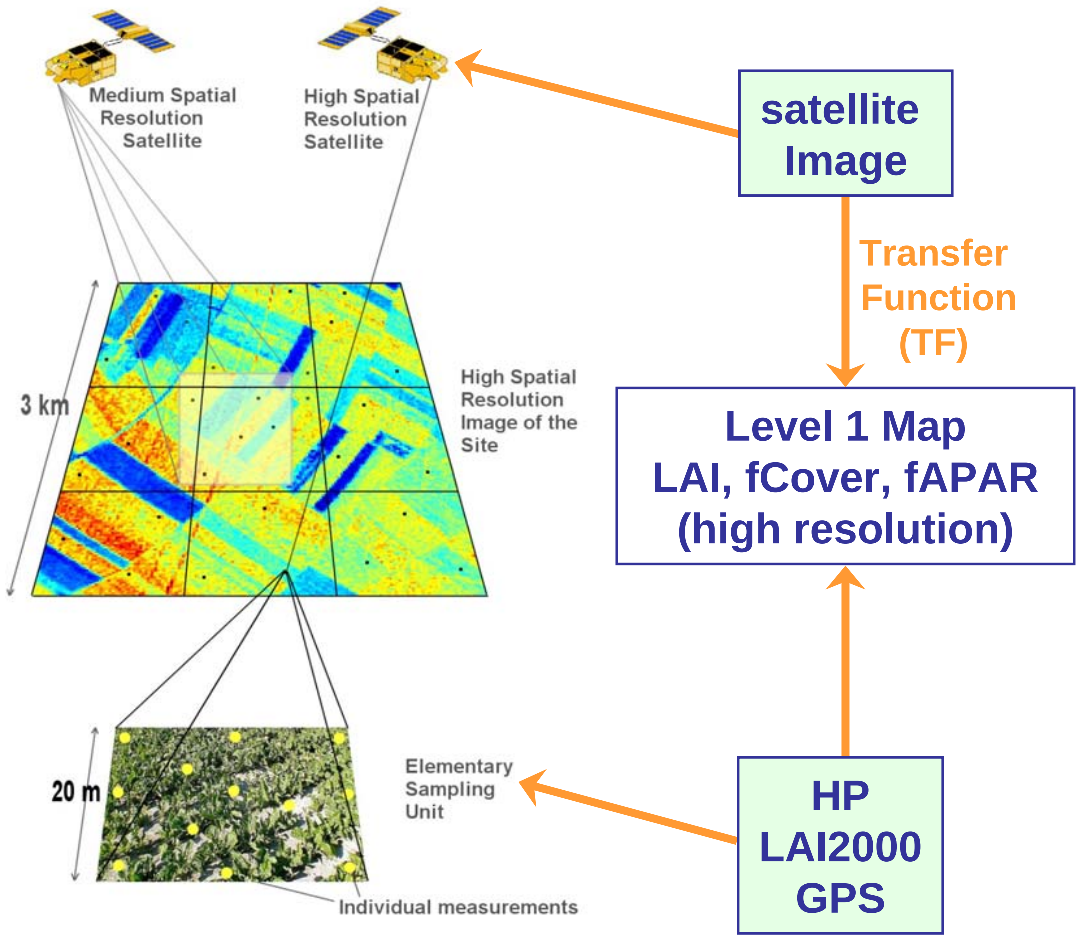
- crops: 10 campaigns
- crops and forest: 1 campaign
- grassland: 4 campaigns
- forest: 5 campaigns
- boreal forest: 3 campaigns
- mixed forest: 1 campaign
- tropical forest: 1 campaign
- palm tree plantation: 1 campaign
- pine forest: 1 campaign
- shrubs: 2 campaigns

Principle of the methodology

From local measurements and high resolution satellite image (mainly SPOT image, but also IRS and Landsat images), **produce of high resolution, level 1, biophysical variable maps**.

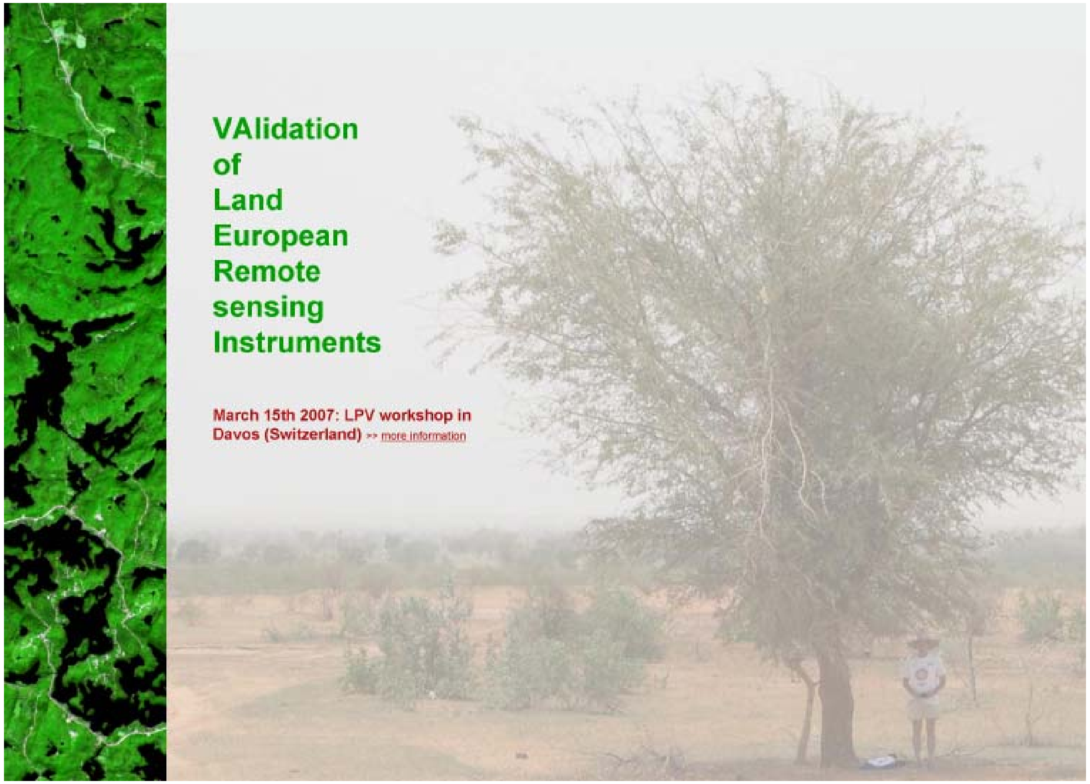
Level 1 map corresponds to the map derived from the determination of a transfer function between reflectance values of the satellite image, acquired during (or around) the ground campaign, and biophysical variable measurements (hemispherical images, LAI 2000).

From local measurements to biophysical variable maps



Where can you find VALERI data?

website: http://www.avignon.inra.fr/valeri



VALERI project in future

Next campaigns processed:

Plan-de-Dieu, 2004 (France)
Järvselja, 2005 (Estonia)
Tähtelä, 2006 (Finland)
Camerons, 2004 (Australia)…

Frequent update the VALERI website (satellite data, hemispherical images processing…)

2007/2008: CNES will continue its efforts (VALERI contract renewal)

II. Data processing sequence in the frame of VALERI project and recent developpements

Philippe Rossello, Frédéric Baret

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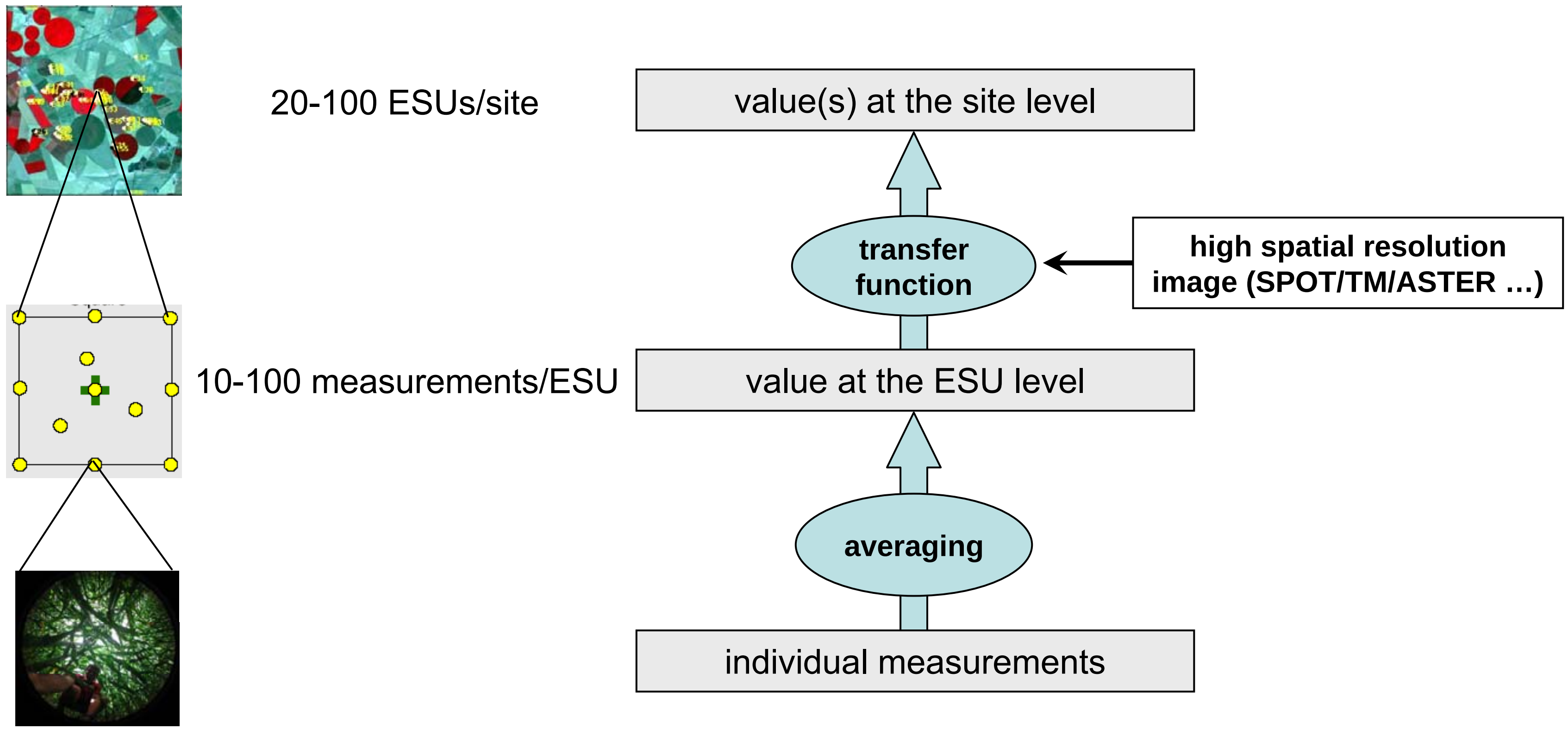
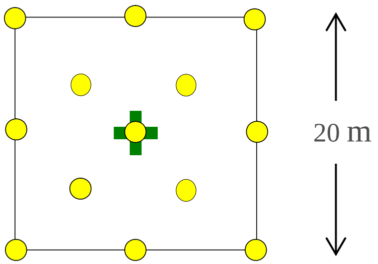
General approach



Spatial sampling at the ESU scale: number and distribution of ground measurements

The spatial sampling of ground measurements consists in setting the minimum number of ESUs (ESU = Elementary Sampling Unit) at the optimal location to provide robust relationships between LAI and high resolution spatial images. An ESU is made of 10 to 15 individual measurements (hemispherical images or LAI 2000).



Example of ESU sampling scheme

Spatial sampling of the measurements

Objectives:

- set the minimum number of ESUs at the optimal location to provide robust relationships between LAI and high resolution spatial images;
- eventually, get a good description of the geostatistics over the site.

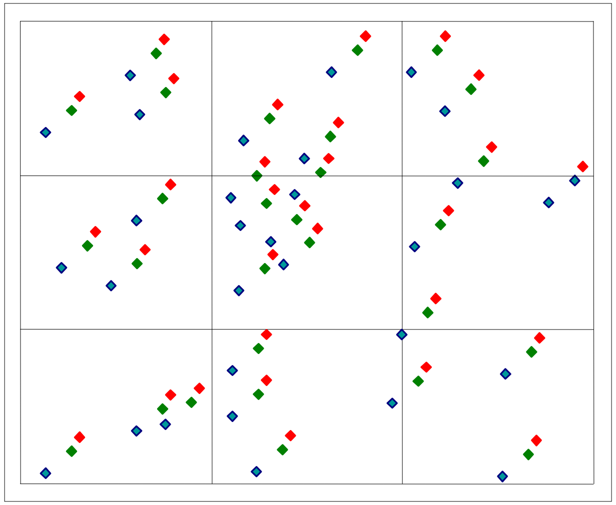
In practice:

- sample in proportion all cover types & variability inside;
- spread spatially equal within $1km^2$ for variogram computation;
- not too close to a landscape boundary;
- sometimes difficulty to access the fields;
- manpower must be reasonable = 3 to 5 ESUs per $1km^2$ ($\cong$ 0.18% of the site).

$\Rightarrow$ **need to evaluate the sampling**

Evaluation of the spatial sampling (1/2)

30 to 50 ESUs to compare with 22500 SPOT pixels.
Comparing directly the two NDVI histograms is not statistically consistent.



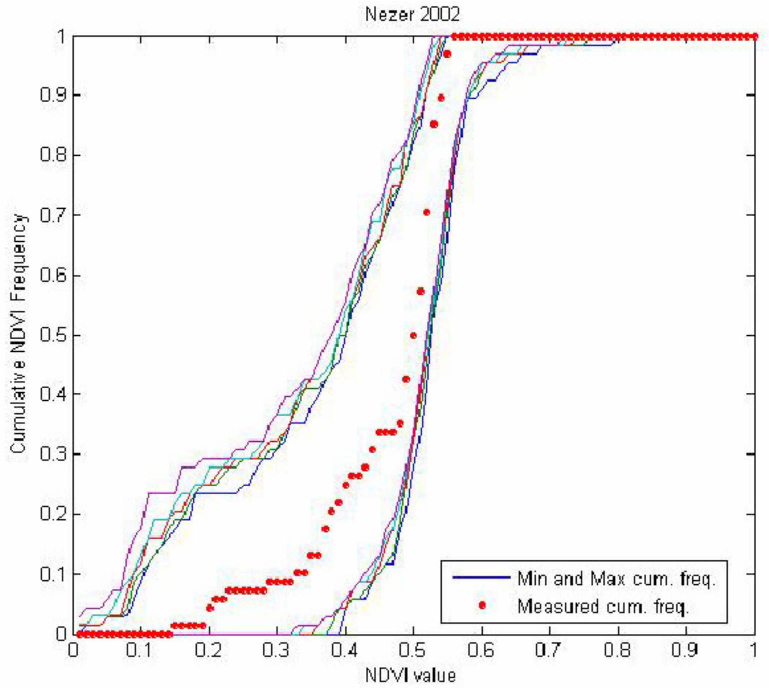
The Monte-Carlo procedure aims at comparing the actual frequency to randomly shifted sampling patterns. It consists in:

1. computing the NDVI cumulative frequency of the 50 exact ESU location
2. applying a unique random translation to the sampling pattern
3. computing the NDVI cumulative frequency of the shifted pattern
4. repeating steps 2 and 3, 199 times with 199 random translation vectors.

Evaluation of the spatial sampling (2/2)

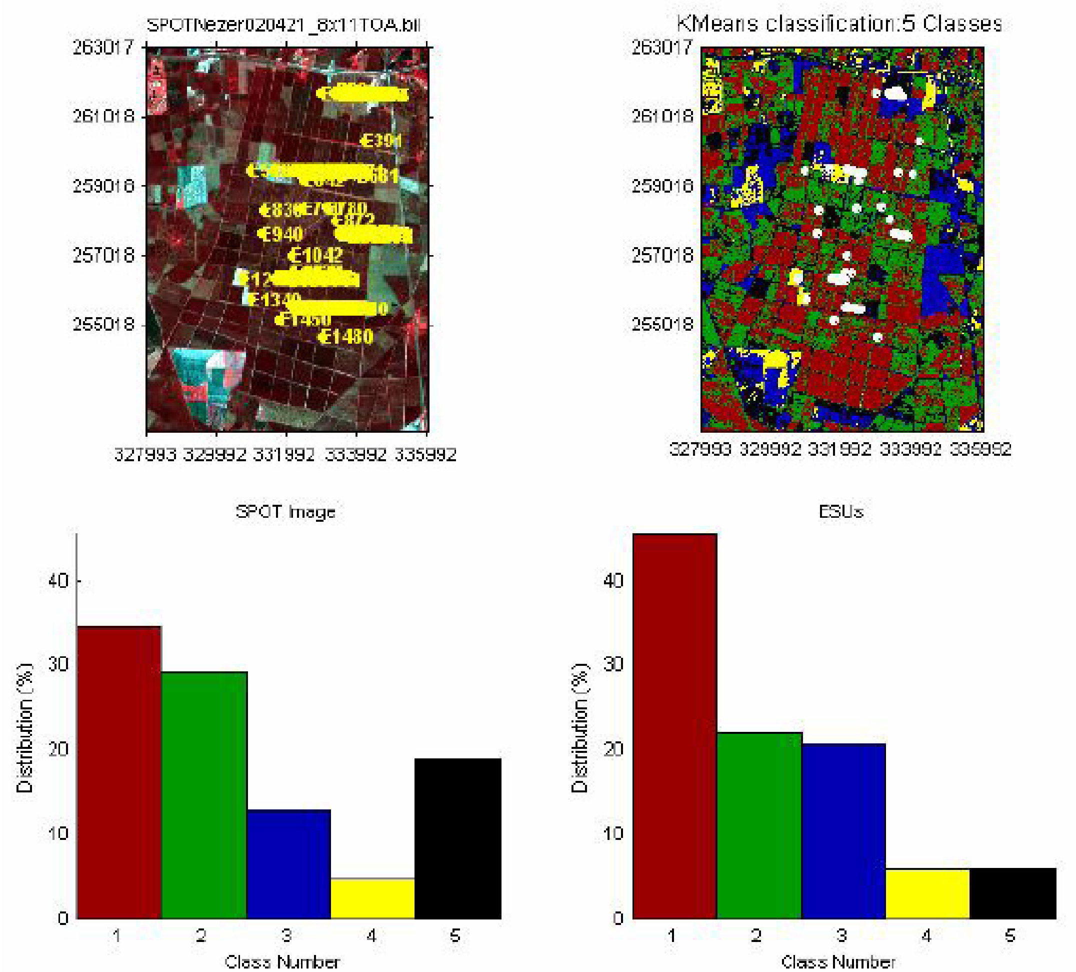
A statistical test on the population of 199+1 cumulative frequencies is then applied:

for a given NDVI level, if the actual ESU density function is between the 5 highest and 5 lowest frequency value, the hypothesis that ESUs and whole site NDVI distributions are equivalent.



Evaluation based on classification

A non supervised classification based on the k_means method was applied to the reflectance of the satellite image.



comparison of the distribution of ESUs between classes:

- population of pixels image;
- population of ESUs.

Evaluation using the convex hulls (1/2)

A test based on the convex hulls is carried out to characterize the representativeness of ESUs in the radiometric space (e.g. the 4 SPOT bands).
A flag image is computed over the reflectances. The result on convex-hulls can be interpreted as:

● pixels inside the ‘strict convex-hull’ = transfer function used as an interpolator

● pixels inside the ‘large convex-hull’: = transfer function used as an extrapolator, but good reliability

● pixels outside the two convex-hulls = transfer function used as an extrapolator which makes the results less reliable.

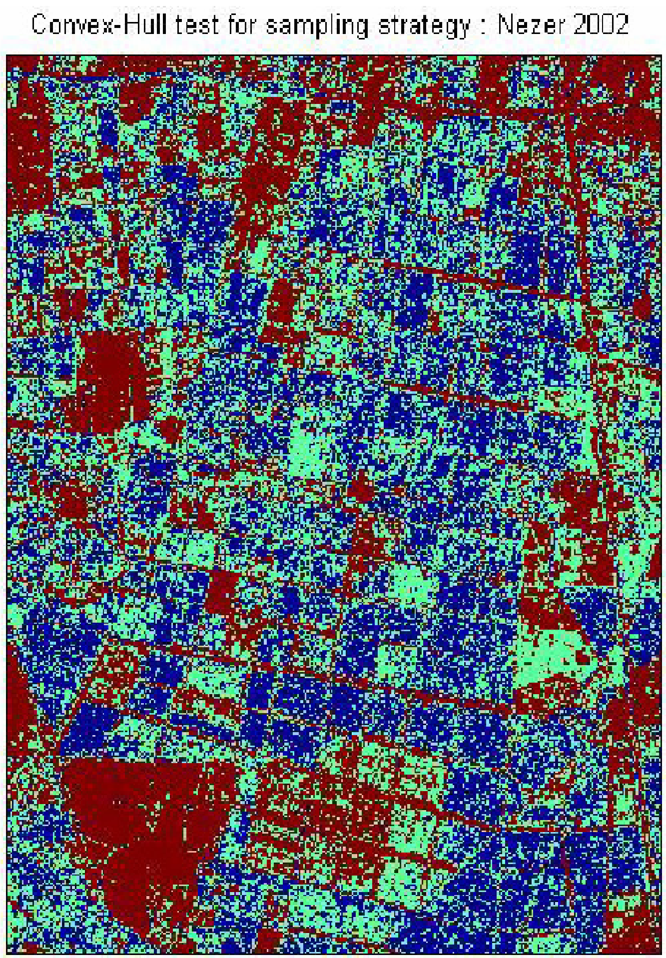
Evaluation using the convex hulls (2/2)

Example: Nezer, 2002

dark blue = strict convex-hull

light blue = large convex-hull

red = extrapolation



Determination of the transfer function (1/3)

The tested methods:

Robust regression:
• iteratively re-weighted least squares algorithm (weights computed at each iteration by applying bisquare function to the residuals).
• results less sensitive to outliers than ordinary least squares regression.

LUT composed of the ESU values:
• LUT with nb ESU elements (3, 4 reflectances + measured LAI)
• cost function:

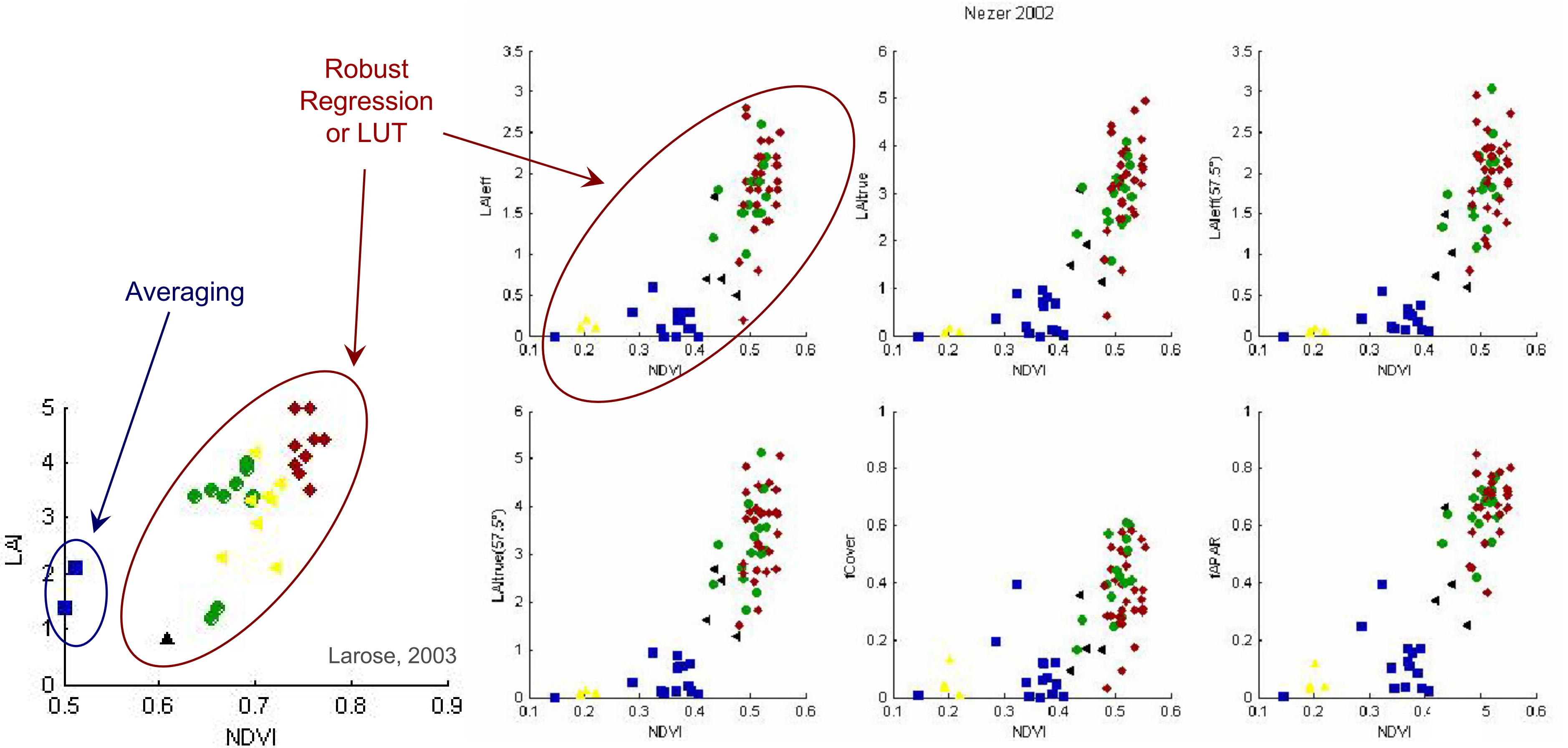
$$C_i^j = \sqrt{\frac{1}{NbBands}\sum_{k=1}^{NbBands}\left[\frac{\left(\rho_i^k - \rho_j^k\right)^2}{\rho_i^k}\right]}$$

• estimated LAI = average value over *x* data minimizing the cost function

AVE
• average value of the biophysical variable measured on the class to each pixel of the satellite image belonging to this class.

Determination of the transfer function (2/3)

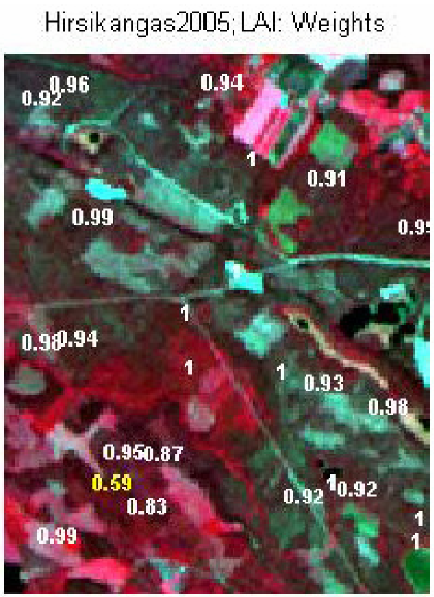
The preliminary analysis of the data consists in showing the different relationships observed between the biophysical variables and the corresponding NDVI on the ESUs.



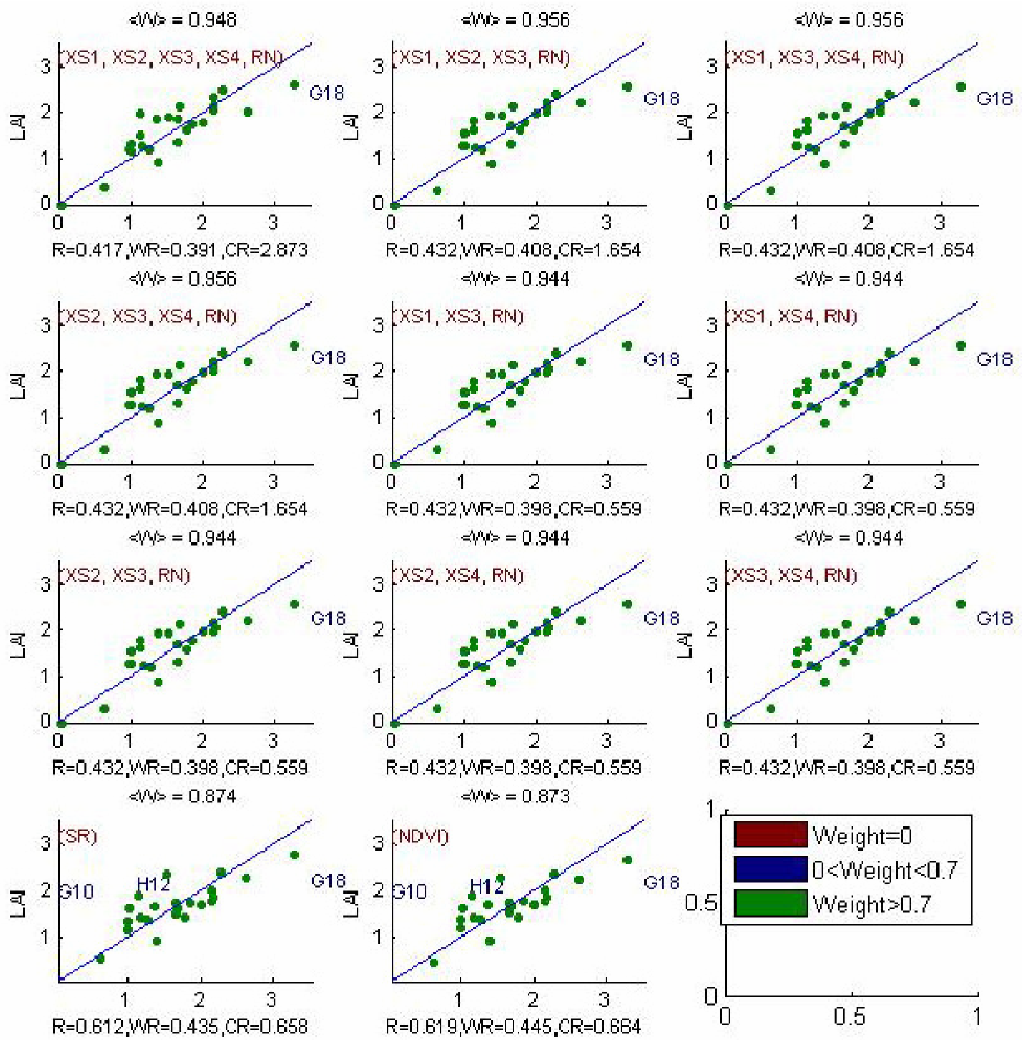
Site	Country	Landcover	Date	AVE	REG	LUT
Aek Loba	Indonesia	plam tree plantation	2001/05	-	+	-
Les Alpilles 1 & 2	France	crops	2001/03	-	+	-
			2002/07	-	+	-
Barrax	Spain	cropland	2003/07	(+)	+	-
Concepción	Chile	mixed forest	2003/01	-	+	-
Counami	French Guiana	tropical forest	2002/10	+	-	-
Demmin	Germany	crops	2004/06	+	-	-
Fundulea	Romania	crops	2001/03	-	+	-
			2002/05	(+)	+	-
			2003/05	(+)	+	-
Gilching	Germany	crops and forest	2002/07	-	+	-
Haouz	Morocco	cropland	2003/03	-	+	-
Hirsikangas	Finland	forest	2003/08	(+)	+	-
			2005/06	-	+	-
Järvselja	Estonia	boreal forest	2002/06	(+)	+	-
			2003/07	-	+	-
Laprida	Argentina	grassland	2001/11	-	+	-
			2002/10	+	-	-
Larose	Canada	boreal forest	2003/08	-	+	-
Larzac	France	grassland	2002/07	-	+	-
Nezer	France	pine forest	2002/04	-	+	-
Romilly-sur-Seine	France	cropland	2000/06	-	-	-
Rovaniemi	Finland	forest	2004/06	-	+	-
			2005/06	(+)	+	-
Sonian forest	Belgium	forest	2004/07	+	-	-
Sud-Ouest	France	crops	2002/07	-	+	-
Turco	Bolivia	cropland	2002/08	-	+	-
			2003/04	-	+	-
Wankama	Niger	grassland	2005/06	+	-	-
				11	**23**	**0**

Choice of the method

For all the ESUs, a single transfer function is computed.

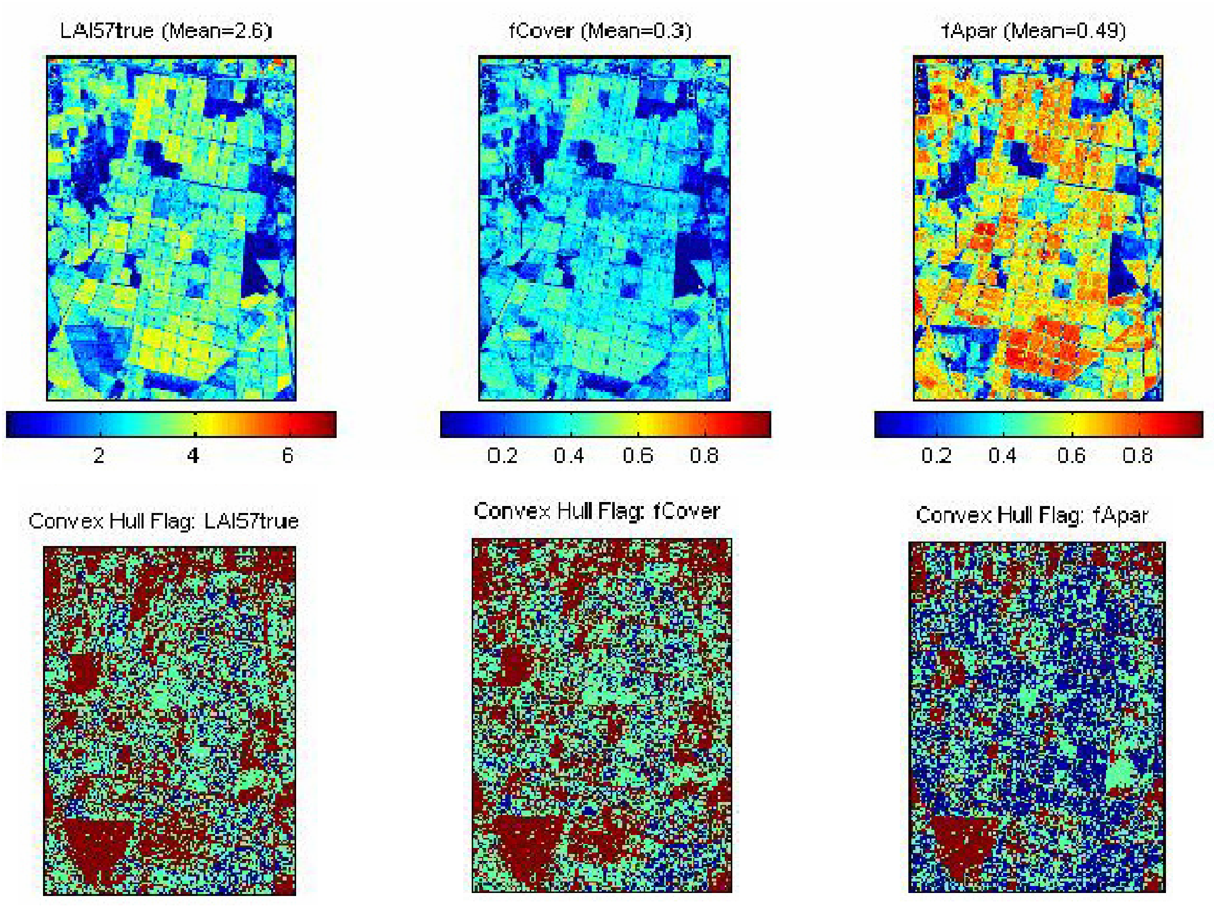


Weights associated to each ESU for the determination of LAI transfer function.



Production of biophysical variable maps

Finally, production of biophysical variable maps at high spatial resolution with associated flags



(Nezer, 2002)

Lessons learnt: possible simplification of the process

Look-up-tables (LUT)

As performances of LUT method were always the poorest, it was proposed to remove this approach from the transfer functions tested.

Regression on logarithm of the reflectance

The REG on the log(ρ) provides sometimes marginally better results than simple linear regressions, but its extrapolation is less robust than just simple linear regressions.

Link: http://www.avignon.inra.fr/valeri/fic_htm/database/main.php

Method to improve the relation between the biophysical variables

P. Rossello, M. Weiss, F. Baret
October 2005

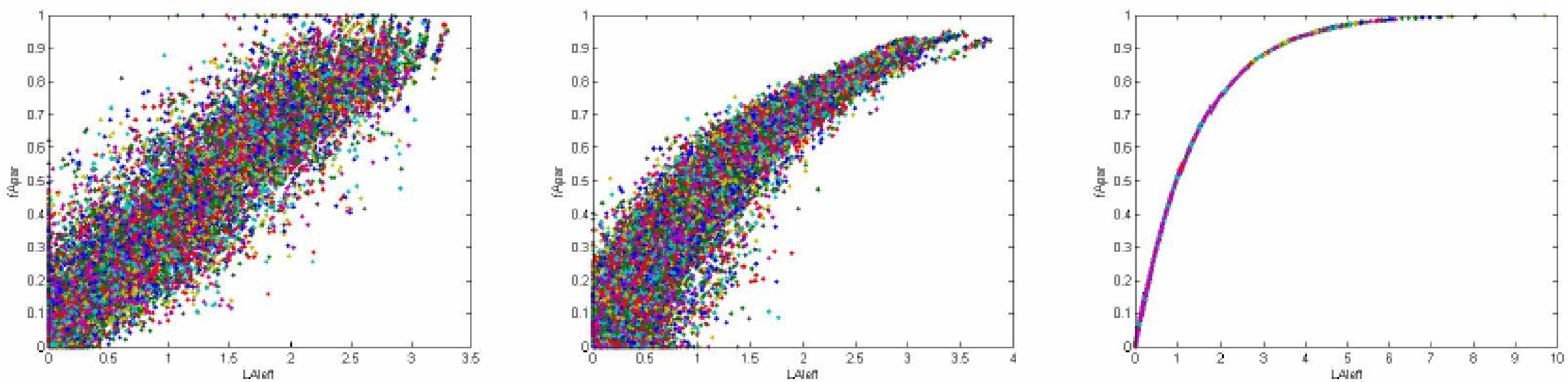
The transfer functions are applied over all band combinations. The band combination giving the best results is selected to estimate the values of the biophysical variables over the whole site. This method is operational and the results of the multiple robust regression are pertinent, but **the dependency between the estimated variables is questionable because of the linear nature of the individual transfer functions.** For example, the relation between LAIeff and fAPAR is linear whereas it should a priori be exponential.

Method to improve the relation between the biophysical variables

P. Rossello, M. Weiss, F. Baret
October 2005

Three methods were tested using the reflectance to calculate LAIeff and fAPAR values with the transfer functions:

- method A: XS1, XS2, XS3, XS4. This method was used up till now;
- method B: XS1, XS2, XS3, XS4, Red*NIR;
- method C: XS1, XS2, XS3, XS4 with LAIeff = k log(fAPAR), where k is fitted using the measured values.



Method A: XS1, XS2, XS3, XS4

Method B: XS1, XS2, XS3, XS4, Red*Nir

Method C: LAIeff = klog(fAPAR)
Combination: XS1, XS2, XS3, XS4

Relations between LAIeff and fAPAR over the whole site using different methods (Alpilles site, 07/2002)

The results show that the addition of the Red*NIR band to the initial combination is enough to improve the relation between LAIeff and fAPAR.

Additional tests showed that when aggregated to 1 km resolution, the average values are almost the same.

Conclusion

The approach is now mature enough to be routinely applied.

Success will depend on:

- quality of ground measurements;
- quality of spatial sampling (number and distribution).

Possible improvements:

- better account for ground measurement and reflectance uncertainties;
- provide estimates of uncertainties after agregation at medium resolution.


Thank you.