GROUND DATA PROCESSING & PRODUCTION OF THE LEVEL 1 HIGH RESOLUTION MAPS

VALERI, June 2001

Nezer site
(pine forest)

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CONTENTS

1. Introduction

This report describes the production of the high resolution, level 1, biophysical variable maps for the Nezer site in June 2001 (see campaign report for more details about the site and the ground measurement campaign: annex or http://www.avignon.inra.fr/valeri). Level 1 map corresponds to the map derived from the determination of a transfer function between reflectance values of the SPOT image acquired during (or around) the ground campaign and biophysical variable measurements (LAI2000 in this case).

The derived biophysical variable maps are:

- Leaf Area Index (LAI): LAI corresponds to effective LAI derived from the description of the gap fraction as a function of the view zenith angle;
- cover fraction (fCover): it is the percentage of soil covered by vegetation between 0° and 7° view zenith angle.

The land cover is mainly composed of maritime pines (forest). The site is nearly flat (for more information, see annex or campaign report: http://www.avignon.inra.fr/valeri).

The site coordinates are described in Table 1:

	France Zone III sud, Nouvelle Triangulation Française IGN (units = meters)		Geographic Lat/Lon, WGS-84 (units = degrees)		UTM 30 North, WGS-84 (units = meters)	
	Easting	Northing	Lat.	Lon.	Easting	Northing
Upper left corner	327992.9100	3 263016.3100	44.61615739	-1.09170020	651404.4430	4942082.9836
Lower right corner	336032.9100	3 251976.3100	44.51984943	-0.98486794	660144.7082	4931589.0035
Center	332012.9100	3 257496.3100	44.56801617	-1.03824037	655774.5624	4936836.0876

Table 1. Description of the site coordinates: they correspond to SPOT image coordinates.

2. Available data

2.1. SPOT Image

The SPOT image was acquired the 20th June 2001 by HRVIR2 on SPOT4 while the ground measurements were carried out from 18th to 29th June 2001. The projection is France Zone III sud, Nouvelle Triangulation Française IGN (please, refer to the campaign report for more details: annex or http://www.avignon.inra.fr/valeri). The image was geo-located by SPOT image (SPOTView Ortho product). No atmospheric correction was applied to the image. However, as the SPOT image is used to compute empirical relationships between reflectance and biophysical variable, we can assume that the effect of the atmosphere is the same over the whole 8 x 11 km site. Therefore, it will be taken into account everywhere in the same way.

Figure 1 shows the relationship between Red and near infrared (NIR) SPOT channels: the soil line is well marked and saturated points are observed. The saturated points correspond to higher reflectance values in Red. The saturation is around 0.32.

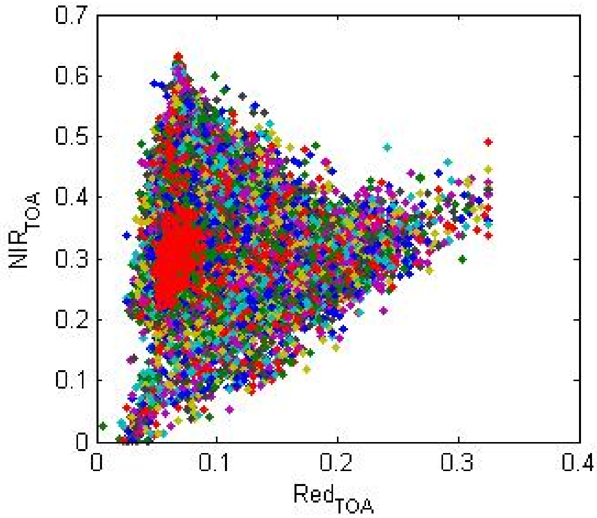

Figure 1. Red/NIR relationship on the SPOT image for Nezer, 2001.

2.2. LAI2000 measurements

For each Elementary Sampling Unit (ESU), the biophysical variables (LAI, fCover) were derived from LAI2000 instrument. In the VALERI context, we are interested in the whole leaf area index (please, refer to the campaign report for more details: annex or http://www.avignon.inra.fr/valeri), therefore, the ESU biophysical variables that are used in the following were computed as:

- LAI = LAI_canopy + LAI_ground
- fCover is the percentage of soil covered by vegetation at 7° view zenith angle (ground level).

Figure 2 shows the distribution of the different measured variables over the sampled ESUs. LAI varies from 0.18 to 5.32 and fCover from 0.039 to 0.96. This range shows a heterogeneous site in terms of LAI. To build the relationships between biophysical variables and SPOT data, the reflectance of a given forest ESU was considered as the average reflectance over the central pixel + the 8 surrounding pixels.

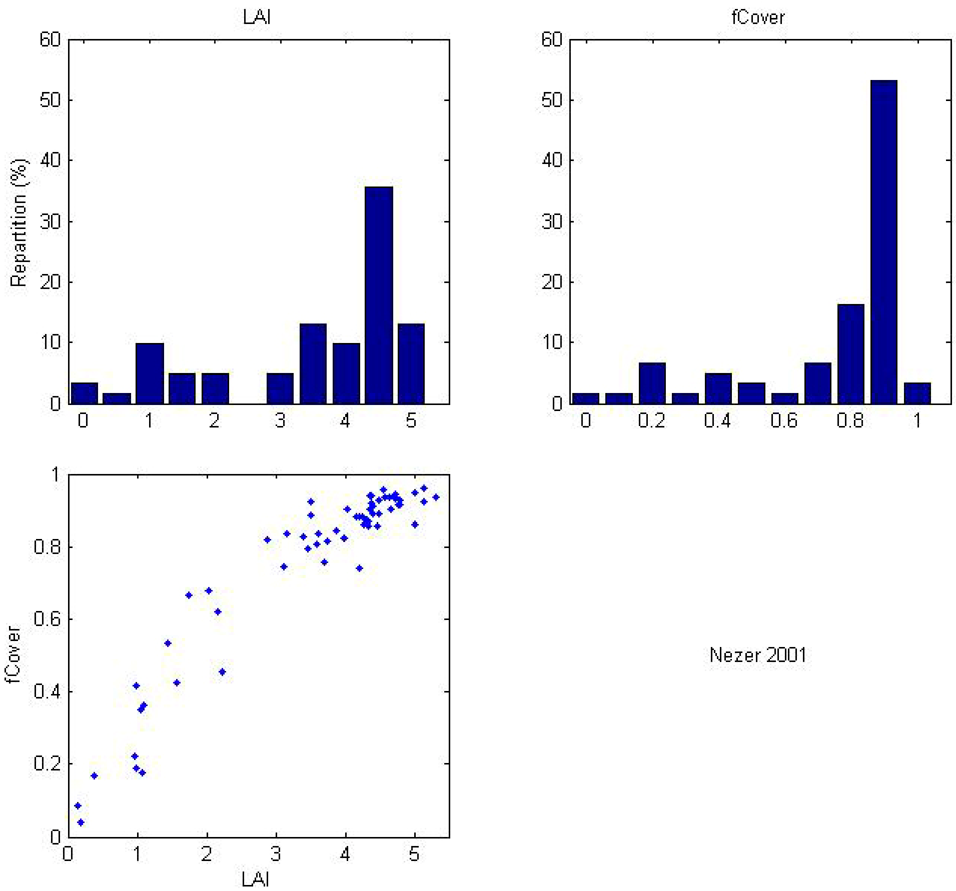

Figure 2. Distribution of the measured biophysical variables over the ESUs.

2.3. Sampling strategy

2.3.1. Principles

The sampling strategy is defined in the campaign report: annex or http://www.avignon.inra.fr/valeri. Figure 3 shows that the 62 ESUs are evenly distributed over the site (8 x 11 km), even if the experiment, like in 2002, was mainly focused in the central part of the study area.

The processing of the ground data has shown that:

• considering that SPOT geo-location and GPS measurements are associated to errors, we found that processed LAI for ESUs E1130, E1200, E181T5 and E632T10 did not correspond to the SPOT pixels in terms of reflectance as compared to the knowledge of the land use: they have been shifted by 1 or 2 pixels;

• E1340 was located on a small plot with a strong heterogeneity on the borders. This ESU was eliminated.

Finally, 61 ESUs have been kept for the computation of the transfer function.

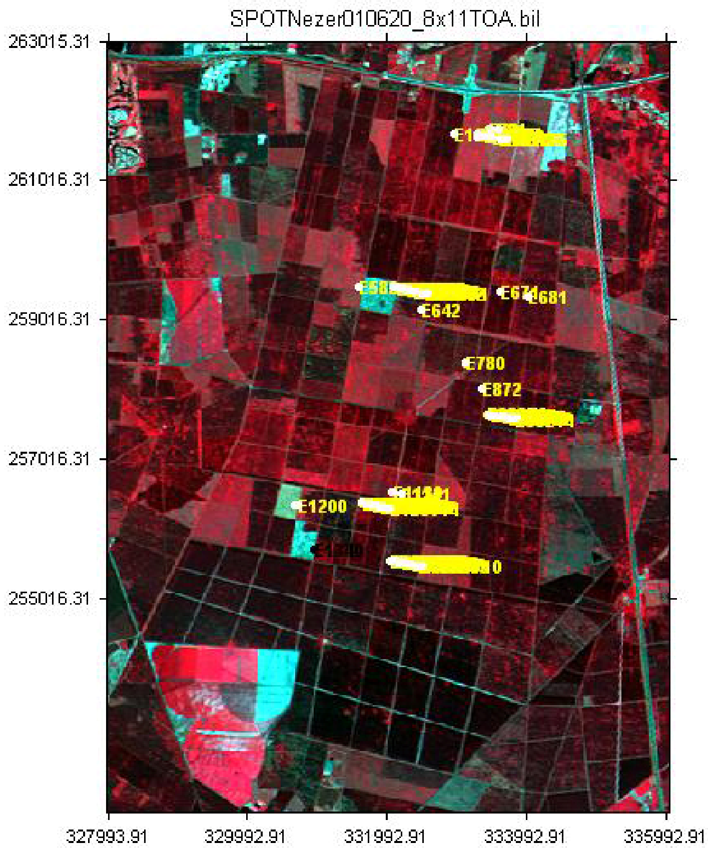

Figure 3. Distribution of the ESUs around the Nezer site.

2.3.2. Evaluation based on NDVI values

The sampling strategy was evaluated using the SPOT image by comparing the NDVI distribution over the site with the NDVI distribution over the ESUs (Figure 4). As the number of pixels is drastically different for the ESU and whole site (WS = 220000 in case of a 8 x 11 km SPOT image at 20 m resolution), it is not statistically consistent to directly compare the two NDVI histograms. Therefore, the proposed technique consists in comparing the NDVI cumulative frequency of the two distributions by a Monte-Carlo procedure which aims at comparing the actual frequency to randomly shifted sampling patterns. It consists in:

1. computing the cumulative frequency of the N pixel NDVI that correspond to the exact ESU locations;
2. then, applying a unique random translation to the sampling design (modulo the size of the image);
3. computing the cumulative frequency of NDVI on the randomly shifted sampling design;
4. repeating steps 2 and 3, 199 times with 199 different random translation vectors.

This provides a total population of $N = 199 + 1$(actual) cumulative frequency on which a statistical test at acceptance probability $1 - \alpha = 95\%$ is applied: for a given NDVI level, if the actual ESU density function is between two limits defined by the $N\alpha / 2 = 5$ highest and lowest values of the 200 cumulative frequencies, the hypothesis assuming that WS and ESU NDVI distributions are equivalent is accepted, otherwise it is rejected.

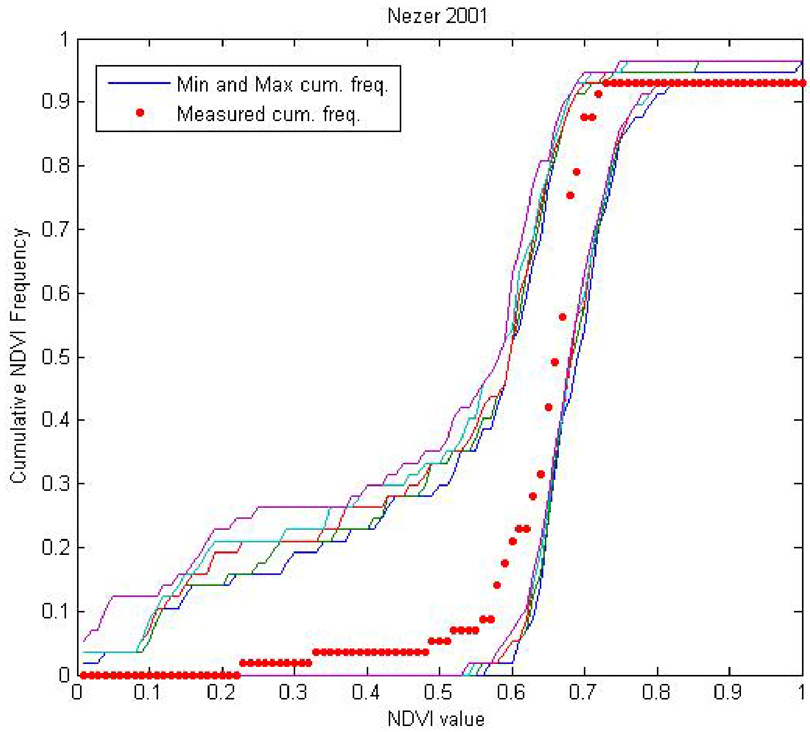

Figure 4. Comparison of the ESU NDVI distribution and the NDVI distribution over the whole image.

Figure 4 shows that the NDVI distribution of the 61 ESUs is good as compared to the NDVI distribution over the whole site since the ‘ESU’ curve is inside the ‘boundary curves’. Note that NDVIs lower than 0.23 (bare soil, roads…), between 0.24 and 0.32 and between 0.34 and 0.48 have not been sampled although they are present in the image. The site is heterogeneous in terms of NDVI values.

2.3.3. Evaluation based on classification

A non supervised classification based on the k_means method (Matlab statistics toolbox) was applied to the reflectance of the SPOT image to distinguish if different behaviours on the image for the biophysical variable-reflectance relationship exist.

A number of 4 classes was chosen (Figure 5). The distribution of the classes on the image and on the ESUs is comparable even if class 2 and class 3 are under-represented while class 1 appears to be over-sampled.

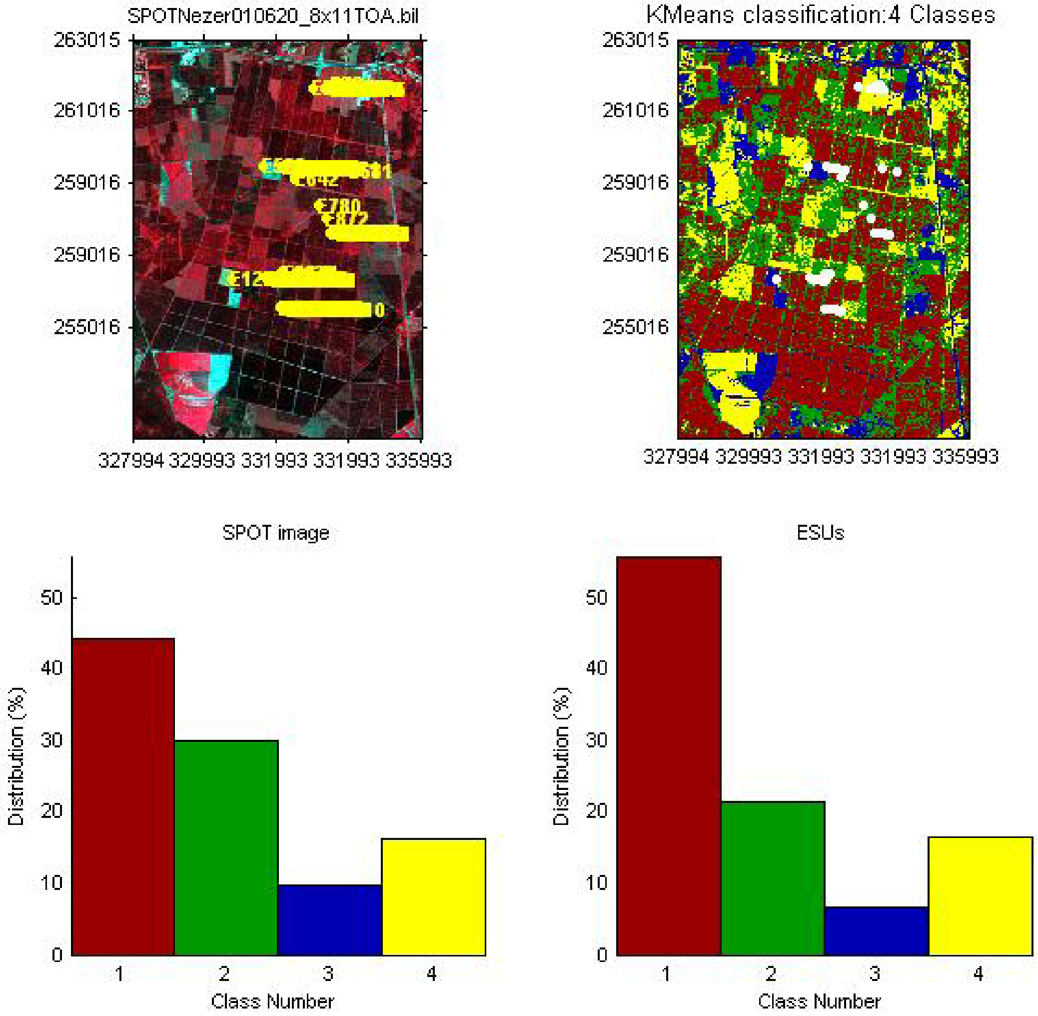

Figure 5. Classification of the SPOT image. Comparison of the class distribution between the SPOT image and sampled ESUs.

Figure 6 shows the different relationships observed between the biophysical variables and the corresponding NDVI on the ESUs, as a function of the SPOT classes determined from non supervised classification.

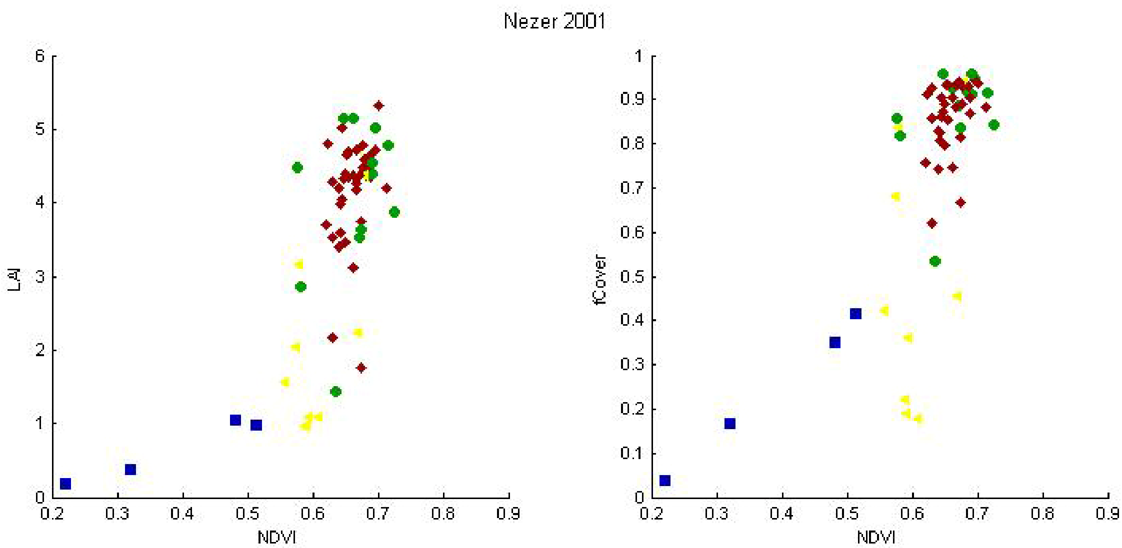

Figure 6. NDVI-Biophysical Variable relationships as a function of SPOT classes

The relationships between the biophysical variables and NDVI is quite good. Even if no different behaviour between the classes can be observed, note that the class 3 is distinguishable from others classes (bare soil, roads, clear cut areas…). However, a single transfer functions will be generated.

2.3.4. Using convex hulls

A test based on the convex hulls was also carried out to characterize the representativeness of ESUs. Whereas the evaluation based on NDVI values uses two bands (red and NIR), this test uses the four bands of the SPOT image. A flag image, is computing over the reflectances (Figure 7). The result on convex-hulls can be interpreted as:

- pixels inside the 'strict convex-hull': a convex-hull is computed using all the SPOT reflectance corresponding to the ESUs belonging to the class. These pixels are well represented by the ground sampling and therefore, when applying a transfer function the degree of confidence in the results will be quite high, since the transfer function will be used as an interpolator;
- pixels inside the 'large convex-hull': a convex-hull is computed using all the reflectance combination (±5% in relative value) corresponding to the ESUs. For these pixels, the degree of confidence in the obtained results will be quite good, since the transfer function is used as an extrapolator (but not far from interpolator);
- pixels outside the two convex-hulls: this means that for these pixels, the transfer function will behave as an extrapolator which makes the results less reliable. However, having a priori information on the site may help to evaluate the extrapolation capacities of the transfer function.

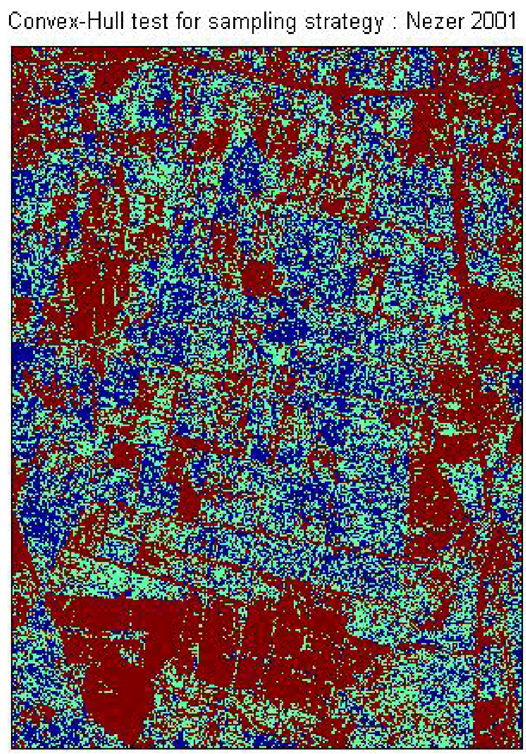

Figure 7. Evaluation of the sampling based on the convex hulls. The map is shown at the bottom: blue and light blue correspond to the pixels belonging to the 'strict' and 'large' convex hulls and red to the pixels for which the transfer function is extrapolating.

This map shows that the representativeness of the ESUs is rather satisfactory even if pixels are outside the two convex-hulls. They correspond to bare soil, roads, paths, clear cut areas, crops, highest NDVI pixels, but also pine stands…

3. Determination of the transfer function for the two biophysical variables: LAI, fCover

3.1. The transfer function considered

Two types of transfer functions are usually tested in the frame of the VALERI project:

- AVE: if the number of ESUs belonging to the class is too low. The transfer function consists only in attributing the average value of the biophysical variable measured on the class to each pixel of the SPOT image belonging to the class;

- REG: if the number of ESUs is sufficient, multiple robust regression between ESUs reflectance (or Simple Ratio) and the considered biophysical variable can be applied: we used the 'robustfit' function from the Matlab statistics toolbox. It uses an iteratively re-weighted least squares algorithm, with the weights at each iteration computed by applying the bisquare function to the residuals from the previous iteration. This algorithm provides lower weight to ESUs that do not fit well. The results are less sensitive to outliers in the data as compared with ordinary least squares regression. At the end of the processing, three errors are computed: classical root mean square error (RMSE), weighted RMSE (using the weights attributed to each ESU) and cross-validation RMSE (leave-one-out method).

For all the classes, the 'REG' function is tested using either the reflectance or the logarithm of the reflectance for any band combination as well as the simple ratio or NDVI. As the method has poor extrapolation capacities, a flag image, based on the convex hulls is computing over reflectances.

3.2. Results

3.2.1. Choice of the method

For all the ESUs, a single transfer function was computed. Figure 8 shows the results obtained for all the possible band combinations using either the reflectance (ρ) or the logarithm of the reflectance (log(ρ)): even if the regression made on the log(ρ) provides slightly better results, the results using the reflectance (ρ) were selected. For LAI and fCover variables, the transfer function using the log(ρ) does not provide pertinent biophysical variable values (very high values). Therefore, the results using the reflectance were selected.

The Red*NIR ('+' or RN) combination is added to all the band combinations (except NDVI and SR). Please read the document (http://www.avignon.inra.fr/valeri/table_methods/new_linear.pdf): "A method to improve the relation between the biophysical variables".

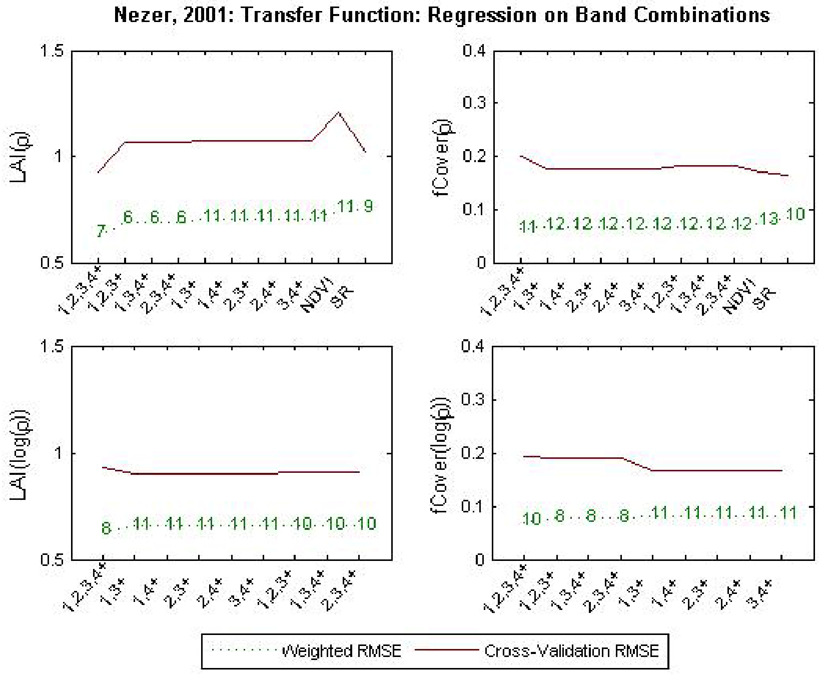

Figure 8. Transfer function: test of multiple regression applied on different band combinations. Band combinations are given in abscissa. The estimated biophysical variable is given in ordinate. Top graphs correspond to regression made on reflectance (ρ): the weighted root mean square error (RMSE) is presented in green along with the cross-validation RMSE in red. The numbers indicate the number of data used for the robust regression with a weight lower than 0.7 that could be considered as outliers. Bottom graphs correspond to regression made on the logarithm of the reflectance.

3.2.2. Choice of the band combination

For LAI, the XS1, XS2, XS3, XS4, RN (Figure 9 and Figure 10) combination on reflectance was selected since it provides the best results. Note that seven weights are lower than 0.7.

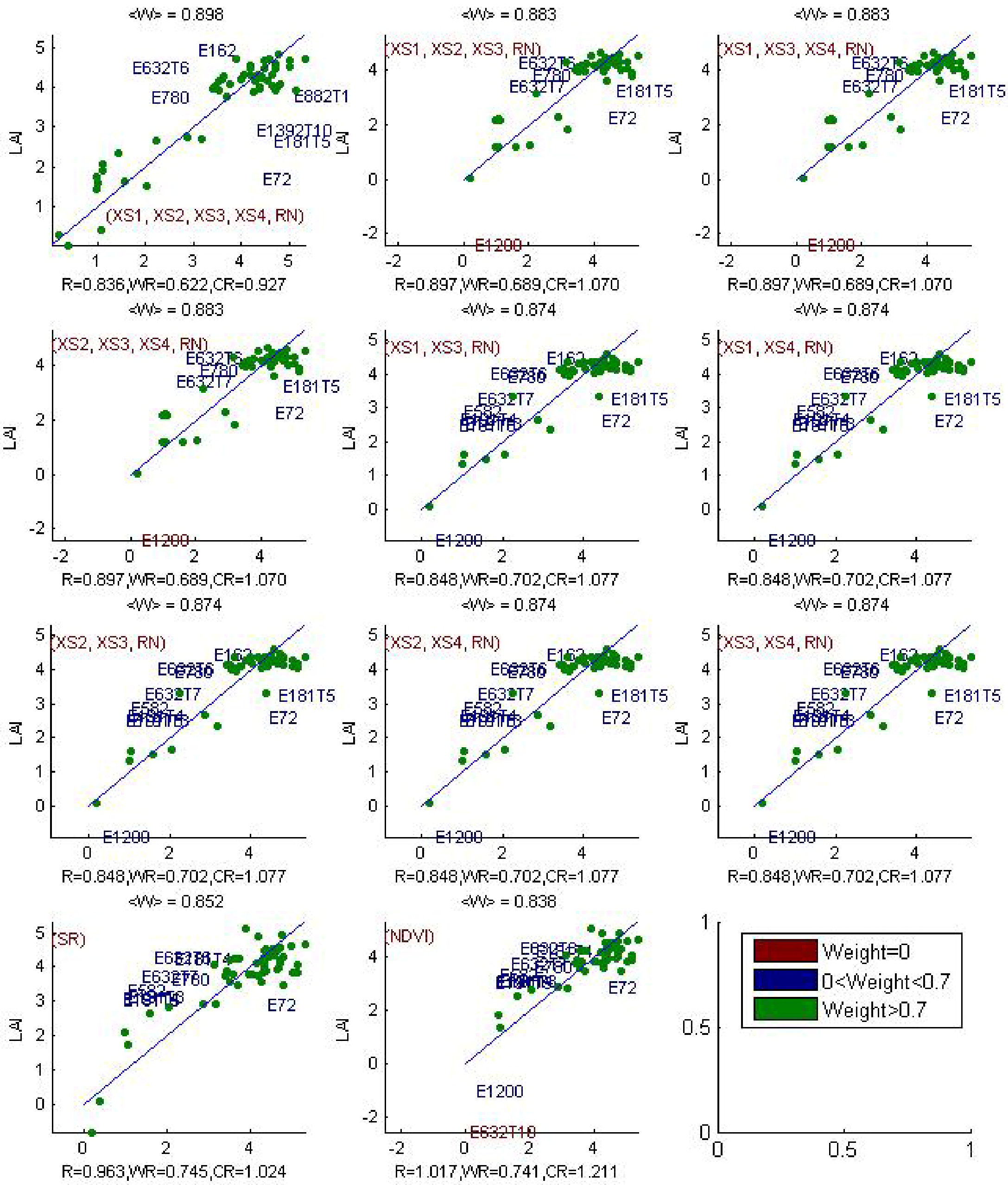

Figure 9. Leaf Area Index: results for regression on reflectance using different band combinations. R is the root mean square error computed between LAIeff and estimated LAIeff. WR is the weighted root mean square error and CR is the cross validation root mean square error.

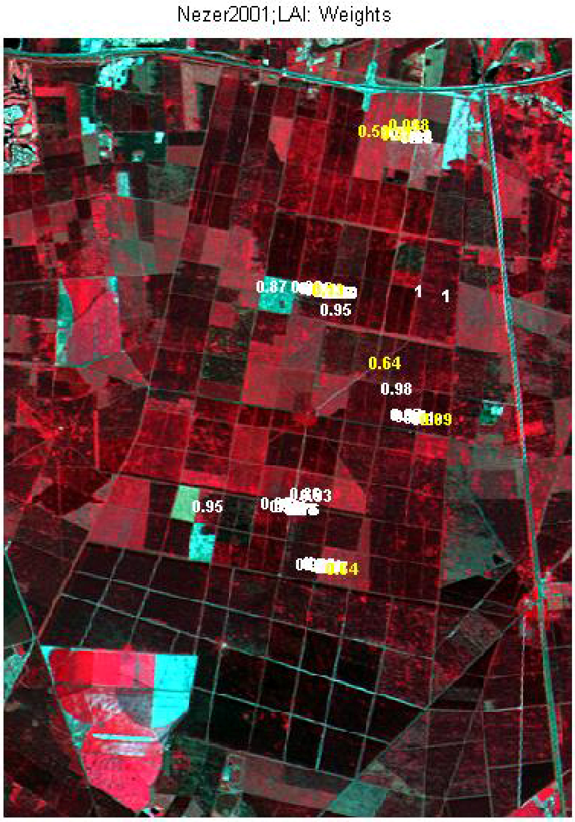

Figure 10. Weights associated to each ESU for the determination of LAI transfer function.

For fCover, the XS2, XS3, RN (Figure 11 and Figure 12) combination on reflectance was selected since it provides a good compromise between the cross-validation RMSE, the weighted RMSE, the RMSE and the number of weights lower than 0.7 (eleven weights four of which are equal to zero). Note that the SR combination on reflectance provides unrealistic values.

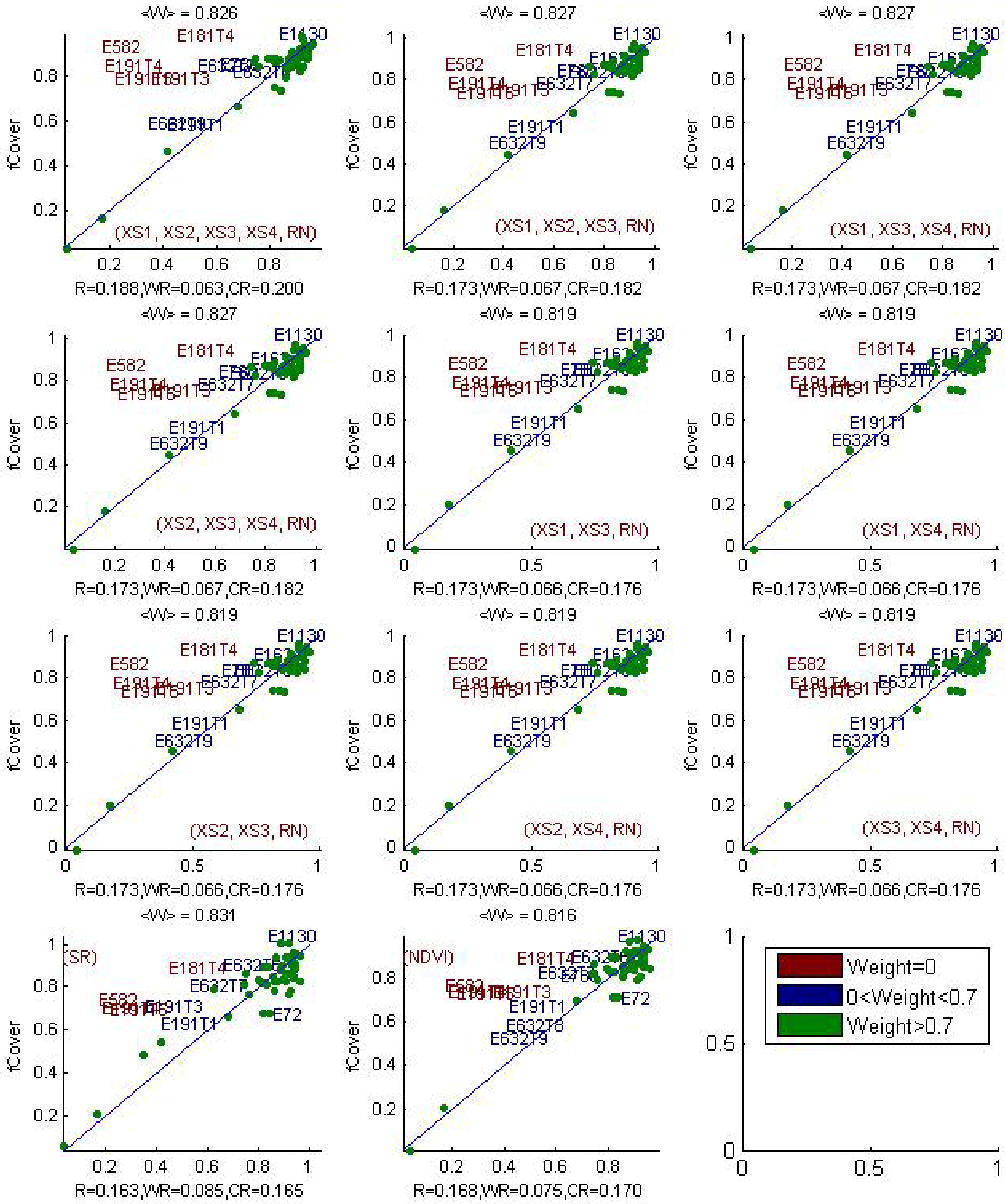

Figure 11. fCover: results for regression on reflectance using different band combinations. R is the root mean square error computed between LAItrue and estimated LAItrue. WR is the weighted root mean square error and CR is the cross validation root mean square error.

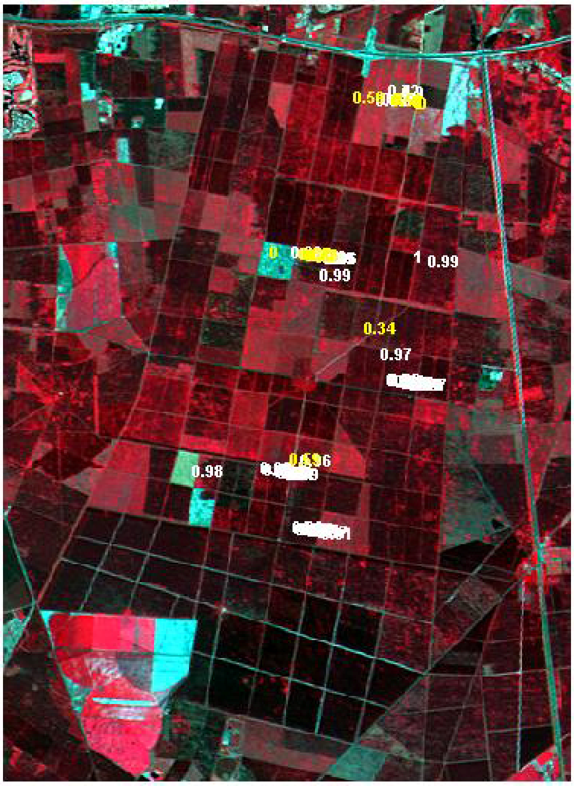

Figure 12. Weights associated to each ESU for the determination of fCover transfer function.

Following, the results of the transfer function (Table 2):

Variable	Band Combination	RMSE	Weighted RMSE	Cross-valid RMSE
LAI	-0.0162 - 15.226(XS1) + 136.7359(XS2) + 26.0456(XS3) - 47.4469(XS4) - 235.8595(RN)	0.836	0.622	0.927
fCover	2.0689 - 14.5463(XS3) - 8.2013(XS4) + 31.0933(RN)	0.173	0.066	0.176

RN = Red*NIR

Table 2. Transfer function applied to the whole site for the different biophysical variables, and corresponding errors

3.3. Applying the transfer function to the Nezer SPOT image extraction

Figure 13 presents the biophysical variable maps obtained with the transfer function described in Table 2 for the classes 1, 2, 3 and 4. The maps obtained for the two variables are usually consistent, showing similar patterns: low LAIeff values where low fCover are observed and conversely… However, a few inconsistent results are produced (Figure 13).

Note that estimated LAI values were higher than 14. As the NDVI values corresponding to ground measurements on the Nezer site were between 0.22 and 0.72, the multi-linear regression is valid only for NDVI ranging between these two values. The extrapolation capacity of this relationship may not be good in certain conditions. Indeed, when applying the relationship on pixels in the image, the regression provides unrealistic results such as extremely high values of LAI. We have no indication in the image and no knowledge of the ground cover which could explain bad regression results. For the LAI pixels higher than 7 (213 pixels, 0.09% of the image), the maximum measured LAI was attributed to these pixels (LAI = 5.5).

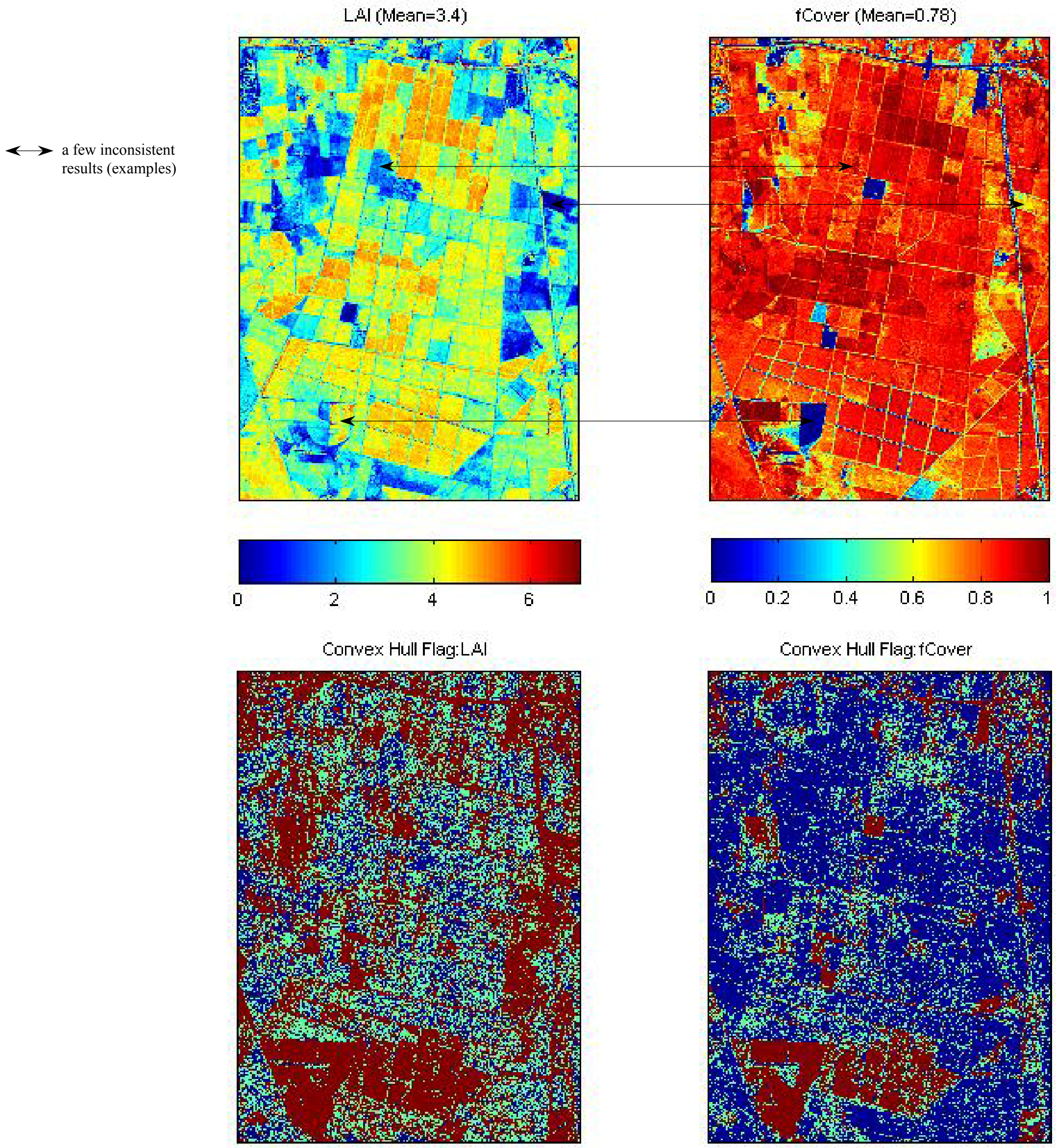

Figure 13. High resolution biophysical variable maps applied on the Nezer site (top). Associated Flags are shown at the bottom: blue and light blue correspond to the pixels belonging to the 'strict' and 'large' convex hulls, red to the pixels for which the transfer function is extrapolating.

The extrapolation corresponds to bare soil, roads, crops, clear cuts, pine stands… The representativeness of the land cover is in question (§2.3.2 and §2.3.4). For fCover, the pixels inside the strict convex hull for are more numerous. This is due to the choice of the band combination. In theory, the more the number of bands increases, the larger the extrapolation is.

4. Conclusion

The 'REG' method is applied to the classes 1, 2, 3 and 4 by using 61 ESUs. The representativeness of the land cover of the different ESUs is quite good. However, the NDVI pixels lower than 0.57, between 0.60 and 0.62 (bare soil, crops, clear cut areas, pine stands) are under-sampled (§2.3.2, §2.3.4). The results of the robust regression are satisfactory and the maps obtained for the biophysical variables are consistent. However, note that a few patterns differ (§3.3). The flag associated to each map show that the extrapolation is mainly related to the problems of representativeness of the land cover and the band combination. For all the variables, the regression coefficients are computed by relating the variable itself to reflectance.

The biophysical variable maps are available in France Zone III Sud (datum: Nouvelle Triangulation Française).

5. Acknowledgements

We want to thank: Dominique **Guyon**, Gaston **Courrier**, Didier **Garrigou**, Sandra **Debesa**, Jean-Marc **Bonnefond**, Jean-Charles **Samalens** (INRA Bioclimatologie, Bordeaux), Jean-Louis **Roujean**, Laurent **Franchisteguy** and Sébastien **Garrigues** (Météo-France, CNRM, Toulouse) for the organisation and participation to the campaign.

ANNEX

VALERI-2001 campaigns in Nezer site (France): 01-17 April 2001 and 18-29 June 2001

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Date of report : 04 April 2002
Updating : 19 April 2003

Participants :

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1. INTRODUCTION

Nezer is located in the Landes forest which covers about 1 million hectares in the South-West of France and where maritime pine (*Pinus pinaster* Ait.) is the dominant species. A VALERI experiment was been already made in the same site in 2000 in the middle of the summer. (Cf. Guyon 2001).

Two measurement campaigns devoted to the VALERI project were carried out in the Nezer site in 2001:

- **from 01 to 17 April 2001 (spring experiment).**

The first campaign was achieved at beginning of spring before the budburst of vegetation. Green LAI of trees and undergrowth was minimal.

- **from 18 to 29 June 2001 (summer experiment).**

The second was performed at the beginning of summer. The growth of vegetation was not finished and green LAI was not yet maximal

The objective of the VALERI project is to estimate LAI and cover fraction at low spatial resolution (1km² for instance) for validating the products resulting from satellites with large swath. The protocol used in 2000 has been modified for improving the spatial accuracy of estimates.

2. LOCATION OF THE TEST SITE

The test site is included into a 8km * 11km grid whose co-ordinates are given in table 1.

	Geographic co-ordinates (geodesic system: WGS84) Longitude ; Latitude	LAMBERT 3 co-ordinates (geodesic system: NTF) Easting ; Northing
Upper left corner	1°05.15' W ; 44°37.20' N	328000 m ; 3263000 m
Lower right corner	0°59.45' W ; 44°34.14' N	336000 m ; 3252000 m

Table 1: Co-ordinates of the 8x11km grid

The projection used is LAMBERT3. All the characteristics of are provided in the following table:

Geodesic Map Datum		Map Projection	
Associated Ellipsoïd	CLARKE1880	Latitude of origin	44°06'00"
Semi-major axe	6378249.2m	Longitude of origin	2°20'14.025"
Semi-minor axe	6 356 515,0m	Parallels 1st 2nd	43°11'57.449" 44°59'45.938
1/flattening			
Eccentricity		Xo: false easting	600000
		Yo: false northing	3200000
		Scale factor	0.99987750

3. DESCRIPTION OF THE TEST SITE

The study area is covered in major part by large and homogeneous (even-aged trees) stands of maritime pine which are intensively managed. The mean size of stands is about 500 x 500m. Their various stages of development range from the sowing to the clear-cutting which is performed mostly after 50 years. The remainder consists mainly of small deciduous wood lands, mosaics of small-sized stands of deciduous species or pine, large agricultural fields, urban and industrial areas, and unmanaged heath lands (see the land use map in figure 1).

In 2001 the experiments were focused in the central part of the study area. This part covers roughly 5*8 km. It is made up mainly of stands of pine and several rare small islands of deciduous trees.

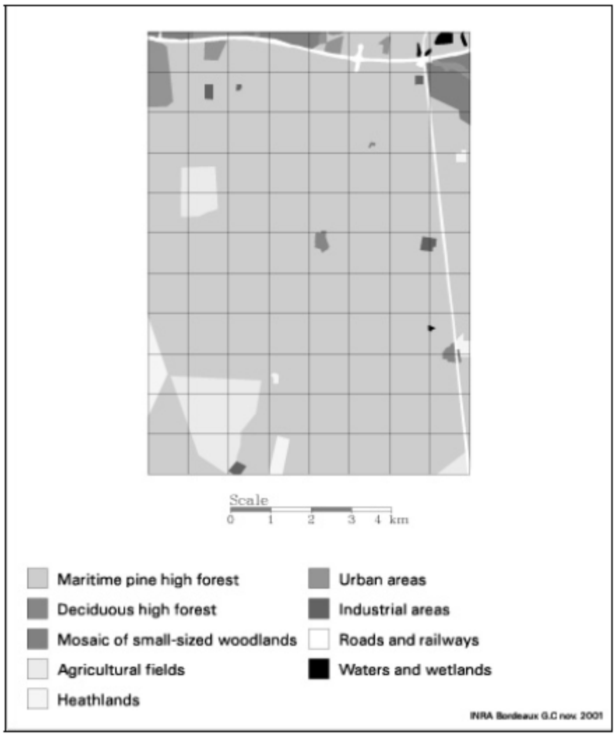


Figure 1: Land use map in 2000 (from aerial photographs and Spot images)

4. GROUND MEASUREMENTS OF LAI

4.1. Protocol of spatial sampling

The protocol used in 2000 has been modified for improving the spatial accuracy of LAI estimates. We reduced the sampled area, the size of sampling plots or ESUs (Elementary Sampling Units) and increased their number.

Selection and spatial distribution of ESUs

Strategy used to define the location of the ESUs:

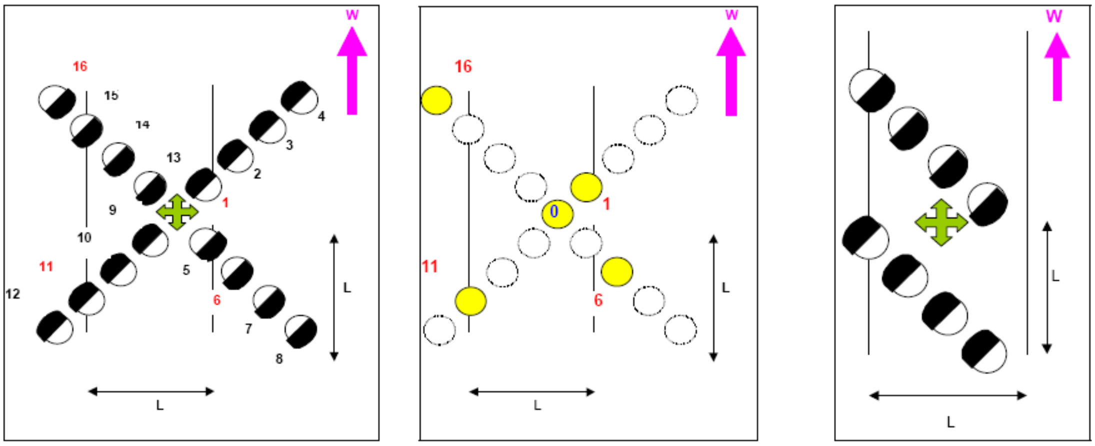
- according to the distribution of the age classes of pine stands;
- accessibility;
- local variability: sampling within several stands with ESUs separated by 50 meters. They constituted five 500m transects. The measurements with this method of sampling were not performed during the spring experiment because of the bad weather;
- spatial variability at larger scale: sampling of the variability between stands with ESUs whose spacing ranges from 100-500 meters to several kilometres.

The geographical location of the centre of each plot is obtained from ground measurements of distance and from the INRA geographic databases. It is given in LAMBERT3 map projection. We did not use GPS system.

Strategies of sampling within ESU

Each ESU covered approximately 20m*20m.
Several strategies of sampling within ESUS were defined:

- cross with 16 points (= cross 16 points): for measurements at ground level, below both layers of trees and undergrowth;
- diagonals with 8 points (= Diag 8 points): for the same purpose; but the number of points was reduced in order to reduce the measurement time. Applied only for the transects;
- cross with 5 points (= cross 5 points): for measurements below the layer of trees.



CROSS 16 points CROSS 5 points DIAG 8 points

L= spacing between rows of trees

Figure 2: Sampling within the ESUs

4.2. Methods of measurement

	Method	Comments
☒	Hemispherical photographs	• **Instrument** : (Nikon coolpix E990, INRA Avignon, marque jaune, serial number= 4070545) + fisheye converter FC-E8 • Data compression: none (format TIFF) • Geometrical resolution: maximal; image size= 1536*2048 pixels • Recording in Black and White • **CP** measurements: Measurement **below the tree storey**: sensor height=0.8 to 1.3m • Illumination conditions: clear, solar elevation <16°, at evening • **Spring**: no measurement • **Summer**: on 12 ESUs, only one photo per ESU, in its center (point 0 of CROSS5points)
☒	LAI2000	• ID and Serial number of instruments: VAL1= PCH-0979, VAL3= PCH-1467, UREF= PCH-0122 • **CP** measurements : Measurement **under the tree storey**: height=0.8 to 1.3m; 3 repetitions on each point; without view cap both below and above the canopy ; sampling strategy : CROSS5points • **CS** measurements : Measurement **under the undergrowth: at ground level**; without view cap above the canopy; with view cap of 180° below the canopy; gap fraction measured on each point in the direction given by the view cap drawn in figure 2 ; with 3 repetitions per point; sampling strategies: CROSS16points or DIAG8points. • Illumination conditions: clear or uniform overcast sky, solar elevation <16°, at evening or morning • **Spring**: only CS measurement on 19 ESUs, not performed in ESUs distributed along the transects because of bad weather. • **Summer**: CS measurement on all ESUs; CP measurement on 12 ESUs

4.3. Characteristics of ESUs

• Spring experiment:

Cf. the Excel file GPSNezer2001Spring.xls:

# GPSnezer2001Spring.xls								
# Spring experiment: 01-17 April 2001								
# location of GCPs, Corners and ESUs on NEZER site, VALERI 2002								
# and dates of measurement								
# 3 revolving teams with Dominique Guyon, Gaston Courrier, Didier Garrigou, Sandra Debesa								
# Team A: D.Guyon, G.Courrier; Team B: D.Guyon, D.Garrigou, Team C: G.Courrier, S.Debesa								
# Projection Name, reference ellipsoid, datum: LAMBERT3, CLARKE1880, NTF								
# column 1: Name								
# Names begining with GCP correspond to Ground control point. A minimum of 4 GCPs must be acquired								
# Name begining with ULC defines the upper left corner of the site								
# Name begining with LRC defines the upper lower right corner of the site								
# Names begining with a number correspond to ESUs								
# columns 2-4 : locating								
# method for locating: noGPS (by measuring distance to landmarks)								
# columns 5-8 : LAI measurements at ground								
# column 5: date of LAI measurements with LAI2000 sensors: L-CS = trees+undergrowth								
# format : DD/MM/YY								
# column 6: sampling within ESU								
# column 7: sensors names: ABOVE/BELOW (only 1 sensor if above=below)								
# column 8 : field of view of sensors (degrees): above/below								
# column 9 : comments								
# mise à jour: 29/04/2003 (correction erreur localisation des ESUs 582000, 120000, 134000)								
# Name	GPS	Easting(m)	Northing(m)	L-CS	ESU sampling	sensors	view field	Comments on the vegetation status, condition of acquisitions, etc...
# 1	2	3	4	5	6	7	8	9
ULC		328000	3263000					
LRC		336000	3252000					
162000	no GPS	332973	3261671	04/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
632000	no GPS	332534	3259396	04/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
642000	no GPS	332492	3259155	12/04/01	cross- 16 points	VAL1/UREF	360/180	pine stand
671000	no GPS	333629	3259420	12/04/01	cross- 16 points	VAL1/UREF	360/180	pine stand
681000	no GPS	334023	3259345	12/04/01	cross- 16 points	VAL1/UREF	360/180	pine stand
780000	no GPS	333133	3258392	12/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
872000	no GPS	333357	3258030	12/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
882000	no GPS	333797	3257596	12/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
1130000	no GPS	332101	3256543	12/04/01	cross- 16 points	VAL1/UREF	360/180	pine stand
1141000	no GPS	332220	3256524	12/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
1200000	no GPS	330734	3256357	12/04/01	cross- 16 points	VAL1/UREF	360/180	clear cutted area (no trees); flowering gorses (Ulex europeaus)
1250000	no GPS	332002	3256323	12/04/01	cross- 16 points	VAL1/UREF	360/180	pine stand
1392000	no GPS	332256	3255527	12/04/01	cross- 16 points	VAL1/VAL3	360/180	pine stand
72000	no GPS	333468	3261754	17/04/01	cross- 16 points	UREF/UREF	180/180	young pine stand: only one vegetation stratum (trees + undergrowth); abundance of flowering Ulex
81000	no GPS	333584	3261734	17/04/01	cross- 16 points	UREF/UREF	180/180	young pine stand: only one vegetation stratum (trees + undergrowth); abundance of flowering Ulex
181000	no GPS	333449	3261644	17/04/01	cross- 16 points	UREF/UREF	180/180	young pine stand: only one vegetation stratum (trees + undergrowth); abundance of flowering Ulex
191000	no GPS	333564	3261619	17/04/01	cross- 16 points	UREF/UREF	180/180	young pine stand: only one vegetation stratum (trees + undergrowth)
582000	no GPS	331592	3259485	17/04/01	cross- 16 points	UREF/UREF	180/180	clear cutted area (no trees)
1340000	no GPS	330960	3255721	17/04/01	cross- 16 points	UREF/UREF	180/180	clear cutted area (no trees)
1340001	no GPS			17/04/01	no measurement	_	_	bare soil - recent tilling

- Summer experiment :

Cf. the Excel file GPSnezer2001Summer.xls:

GPSnezer2001Summer.xls
Summer experiment: 18-29 June 2001
location of GCPs, Corners and ESUs on NEZER site, VALERI 2002
and dates of measurement
several revolving teams with Dominique Guyon, Gaston Courrier, Didier Garrigou, Sandra Debesa, Laurent Franchistéguy, Sébatien Garrigues, Jean-Charles Samalens, Jean-Paul Guyon
Projection Name, reference ellipsoid, datum: LAMBERT3, CLARKE1880, NTF
column 1: Name
Names begining with GCP correspond to Ground control point. A minimum of 4 GCPs must be acquired
Name begining with ULC defines the upper left corner of the site
Name begining with LRC defines the upper lower right corner of the site
Names begining with a number correspond to ESUs
columns 2-4 : locating
method for locating: noGPS (by measuring distance to landmarks)
columns 5-13 : LAI measurements at ground
column 5-12 : measurements with LAI2000 sensors: L-CS = trees+undergrowth
column 5: date DD/MM/YY
column 6: sampling within ESU
column 7: sensors names: ABOVE/BELOW (only 1 sensor if above=below)
column 8 : field of view of sensors (degrees): above/below
column 9-12 : measurements with LAI2000 sensors: L-CP = trees
column 9: date DD/MM/YY
column 10: sampling within ESU
column 11: sensors names: ABOVE/BELOW (only 1 sensor if above=below)
column 12 : field of view of sensors (degrees): above/below
column 13-13 : measurement with Hemispherical photos: hp-CP = trees layer
only one photo per ESU, in its center ; (Nikon coolpix E990 (INRA Avignon, marque jaune, serial number= 4070545)
column 13 : date DD/MM/YY
column 14 : comments
mise à jour: 29/04/2003 (correction erreur localisation des ESUs 582000, 120000, 134000)

# Name	GPS	Easting(m)	Northing(m)	L-CS	ESU sampling	sensors	view field	L-CP	ESU sampling	sensors	view field	hp-CP	Comments on the vegetation status, condition of acquisitions, etc...
# 1	2	3	4	5	6	7	8	9	10	11	12	13	14
ULC		328000	3263000										
LRC		336000	3252000										
72000	no GPS	333468	3261754	29/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth);
81000	no GPS	333584	3261734	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth);
162000	no GPS	332973	3261671	19/06/01	cross- 16 points	VAL1/UREF	360/180	29/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
181000	no GPS	333449	3261644	22/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth);
181001	no GPS	333498	3261635	22/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
181003	no GPS	333400	3261653	22/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
181004	no GPS	333351	3261662	22/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
181005	no GPS	333302	3261671	22/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
191000	no GPS	333564	3261619	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
191001	no GPS	333515	3261628	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
191003	no GPS	333613	3261610	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
191004	no GPS	333662	3261601	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
191005	no GPS	333711	3261592	22/06/01	diag- 8 points	VAL1/VAL3	360/180						young pine stand: only one vegetation stratum (trees + undergrowth)
582000	no GPS	331592	3259485	19/06/01	cross- 16 points	VAL1/UREF	360/180						clear cutted area (no trees)
632000	no GPS	332534	3259396	19/06/01	cross- 16 points	VAL1/UREF	360/180	28/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
632001	no GPS	332583	3259387	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand;
632002	no GPS	332534	3259396	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand; = ESU 632000
632003	no GPS	332485	3259405	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand
632004	no GPS	332436	3259414	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand
632005	no GPS	332387	3259423	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand
632006	no GPS	332337	3259433	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand: low trees density
632007	no GPS	332288	3259442	20/06/01	diag- 8 points	VAL1/UREF	360/180						pine stand: low trees density ;
632008	no GPS	332239	3259451	20/06/01	diag- 8 points	VAL1/UREF	360/180						clear cutted area (no trees)
632009	no GPS	332193	3259460	20/06/01	diag- 8 points	VAL1/UREF	360/180						clear cutted area (no trees)
632010	no GPS	332141	3259469	20/06/01	diag- 8 points	VAL1/UREF	360/180						young pine stand: seedlings
642000	no GPS	332492	3259155	19/06/01	cross- 16 points	VAL1/UREF	360/180	28/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
671000	no GPS	333629	3259420	19/06/01	cross- 16 points	VAL1/UREF	360/180	29/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
681000	no GPS	334023	3259345	19/06/01	cross- 16 points	VAL1/VAL3	360/180	29/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
780000	no GPS	333133	3258392	19/06/01	cross- 16 points	VAL1/UREF	360/180	28/06/01	cross- 5 points	VAL1/VAL3	360/360	29/06/01	pine stand
872000	no GPS	333357	3258030	19/06/01	cross- 16 points	VAL1/VAL3	360/180	28/06/01	cross- 5 points	VAL1/VAL3	360/360	29/06/01	pine stand
882000	no GPS	333797	3257596	19/06/01	cross- 16 points	VAL1/VAL3	360/180	29/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
882001	no GPS	333847	3257587	22/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882002	no GPS	333797	3257596	22/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand ; = ESU 882000
882003	no GPS	333747	3257605	22/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882004	no GPS	333697	3257614	22/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882005	no GPS	333647	3257623	22/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882007	no GPS	333547	3257642	28/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882008	no GPS	333497	3257651	28/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
882009	no GPS	333447	3257660	28/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1130000	no GPS	332101	3256543	19/06/01	cross- 16 points	VAL1/UREF	360/180	28/06/01	cross- 5 points	VAL1/UREF	360/360	28/06/01	pine stand
1141000	no GPS	332220	3256524	19/06/01	cross- 16 points	VAL1/VAL3	360/180	29/06/01	cross- 5 points	VAL1/UREF	360/360	29/06/01	pine stand
1200000	no GPS	330734	3256357	28/06/01	cross- 16 points	VAL1/VAL3	360/180						clear cutted area (no trees)
1250000	no GPS	332002	3256323	19/06/01	cross- 16 points	VAL1/VAL3	360/180	28/06/01	cross- 5 points	VAL1/UREF	360/360	28/06/01	pine stand
1250001	no GPS	332052	3256314	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250002	no GPS	332002	3256323	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand ; = ESU 125000
1250003	no GPS	331952	3256332	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250004	no GPS	331902	3256341	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250005	no GPS	331852	3256350	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250006	no GPS	331802	3256360	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250007	no GPS	331752	3256369	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250008	no GPS	331702	3256378	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1250009	no GPS	331652	3256387	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1340000	no GPS	330960	3255721	28/06/01	cross- 16 points	VAL1/VAL3	360/180						young pine stand: seedlings
1392000	no GPS	332256	3255527	19/06/01	cross- 16 points	VAL1/VAL3	360/180	28/06/01	cross- 5 points	VAL1/UREF	360/360	28/06/01	pine stand
1392001	no GPS	332056	3255564	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392002	no GPS	332106	3255554	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392003	no GPS	332156	3255545	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392004	no GPS	332206	3255536	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392005	no GPS	332256	3255527	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand ; = ESU 1392000
1392006	no GPS	332306	3255518	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392007	no GPS	332356	3255509	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392008	no GPS	332406	3255500	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392009	no GPS	332456	3255490	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand
1392010	no GPS	332505	3255481	20/06/01	diag- 8 points	VAL1/VAL3	360/180						pine stand

4.4. Inter-calibration of the three LAI2000 sensors

• Sensors characteristics :

Id	VAL1	VAL3	UREFV
Serial Number	PCH-0979	PCH-1467	PCH-0122
Calibration coefficients :			
Ring 1 (7°)	4068	4032	4026
Ring 2 (23°)	1260	1258	1248
Ring 3 (38°)	1000	1000	1000
Ring 4 (53°)	1007	1000	1016
Ring 5 (68°)	1378	1278	1437

• Inter-calibration measurements:
- location: INRA Bioclimatologie, Bordeaux : 44.79°N, 0.57°W;
- clear sky;
- azimutal field of view : 360° (no view cap);
- time sampling : 15s.

date	atmospherics Conditions	Time TU	sun elevation
27 March 2001	Heterogeneous haze	7h19-7h35	14-17°
30 March 2001	Several cirrus and alto cumulus	7h12-7h35	13-18°
3 April 2001	Clear sky	6h46-7h35	11.5-20°
20 June2001	Clear sky	5h35-6h00	11.1-15.3°

The values of inter-calibration coefficients resulting from these experiments showed a discrepancy with those obtained on July 2000 (cf. report Guyon, 2001) and March 2002 (Cf. reports Guyon, 2002).

VAL3=a3 VAL1				
1/a3	24/07/2000	03/04/2001	26/06/2001	27/03/2002
7	0.3299	0.2961	0.3006	0.3327
23	0.3338	0.3011	0.3041	0.3372
38	0.3404	0.3169	0.3117	0.3478
53	0.3512	0.3294	0.3176	0.3590
68	0.3691	0.3376	0.3197	0.3687
urefv = a0 VAL1				
1/a0	24/07/2000	03/04/2001	26/06/2001	
7	0.8455	0.8969	0.8717	
23	0.8445	0.8857	0.8723	
38	0.8315	0.8821	0.8641	
53	0.8077	0.8677	0.8421	
68	0.7733	0.7966	0.8156	

A lack of co-linearity of the responses when the solar elevation was increasing (>11°) could explain the results. The coefficient values for VAL3 in 2000 and 2002 resulted from observations when sun elevation was low (<11°). They were very similar. We thus assumed that the drift of the sensors was very slight during this lapse of time

• Coefficient values used:

Consequently we used the coefficient values estimated from measurements performed on the 24th July 2000 (solar elevation: 3 to 7°) (Cf. report Guyon, 2001):

Val1 : Pch-0979	val3 : pch-1467			Urefv : pch-0122		
	val3 = a3 VAL1			urefv = a VAL1		
Ring	a3	1/a3	2*(1/a3)	a0	1/a0	2*(1/a0)
1 (07°)	3.0314	0.3299	0.6598	1.1827	0.8455	1.6910
2 (23°)	2.9956	0.3338	0.6676	1.1841	0.8445	1.6890
3 (38°)	2.9380	0.3404	0.6807	1.2027	0.8315	1.6629
4 (53°)	2.8471	0.3512	0.7025	1.2381	0.8077	1.6154
5 (68°)	2.7093	0.3691	0.7382	1.2932	0.7733	1.5466

They are suitable for measuring without view cap both below and above the canopy. We approximated their values by dividing a*i* by 2 for measurements with a view cap of 180° below the canopy and without view cap above the canopy.

5. ANCILLARY DATA

5.1. Atmosphere properties

• Spring experiment:

Any measurement with sun photometer was not performed. However data of incoming global and diffuse radiation was available from 19 March to 27 March and from 3 to 17 April 2001. It was provided from two sensors of photosynthetic active radiation located in the Carboreuroflux site at about 25 km (44°42'N, 0°46'W;) from the Nezer site.

• Summer experiment:

For atmospheric correction of remote sensing data, aerosol optical depth and water vapour content were provided by AERONET network from measurements with the automatic sun photometer located in the INRA Research Centre of Bordeaux (N44°47', W00°34'), at about 40 km from the Nezer site. The photometer has been installed on the 15th May 2001.

Global and diffuse incoming radiations were measured in the NEZER site for assessing horizontal variations of atmosphere properties. An integrated sensor of photosynthetic active radiation (BF2, Delta-T Devices Ltd, Inra-Avignon) was used. It was set in the northern part of NEZER (…….m Easting, …….m Northing Lambert3). Measurements were recorded from 28 June to 23 July 2001. The PAR sensors of the Carboreuroflux site provided complementary data for the period of 18 June to 23 July 2001.

5.2 Ground observations on vegetation conditions

Observations on the undergrowth vegetation of sampled plots: phenology, development and cover fraction.
Illustration with photographs.

Spring experiments: on 13th and 17th April 2001
Summer experiment: on 9th and 10th July 2001

6. SPOT IMAGES

Satellite used:	SPOT4 HRVIR2
Level of processing:	SPOTVIEW Basic Ortho
Projection type:	LAMBERT3
Date:	02 April 2001, 20 June 2001

7. BIBLIOGRAPHY

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