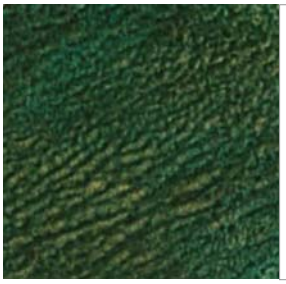
GROUND DATA PROCESSING & PRODUCTION OF THE LEVEL 1 HIGH RESOLUTION MAPS



VALERI 2001

Gourma site
(grassland)

Philippe Rossello

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CONTENTS

1. Introduction

Within the framework of the VALERI project, the objective is the production 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 (LAI-2000 or hemispherical images). The spatial sampling of ground measurements consists in setting the minimum number of Elementary Sampling Units (ESU) at the optimal location to provide robust relationships between LAI and high resolution spatial images. An elementary sampling unit is made of 10 to 15 individual measurements. For information, the sampling protocol is available on the VALERI website: http://www.avignon.inra.fr/valeri/fic_htm/methodology/main.php

Like in 2000, the ground campaign of Gourma site (annex or http://www.avignon.inra.fr/valeri) provided an "accurate estimation of 3 parameters characterising the vegetation layer, namely the herbaceous cover fraction (fCover), the herbage mass and the Leaf Area Index (LAI) at the scale of 1 x 1 km cells". The methodology is described in the campaign report (annex or http://www.avignon.inra.fr/valeri). Note that the herbage mass variable is not taken in account in the VALERI project. In October 2001, LAI was estimated from herbage mass (Bm) and Specific Leaf Area (SLA) measurements while fCover from visual estimation of the vegetation cover fraction.

The Gourma site is located within the "sahelian zone, in the Malian Gourma. The landscape is characterised by "gently undulating dunes with a sand content of about 90%". The site coordinates are described in Table 1:

	UTM 30, North, WGS-84 (units = meters)		Geographic Lat/Lon WGS-84 (units = degrees)	
	Easting	Northing	Lat.	Lon.
Upper left corner	653654.3890	1696268.3260	15.33844936	-1.56860860
Lower right corner	656674.3890	1693248.3260	15.31097236	-1.54067118
Center	655164.3890	1694758.3260	15.32471123	-1.55463898

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

2. Available data

No satellite image was available during or around the ground campaign (28 September - 6 October 2001). However, the following figure shows that the Gourma site is homogeneous.

Figure. Google Earth image[1] over the Gourma site (3 x 3 km grid)

For each 1 x 1 km cell, the biophysical variable value was estimated (details in annex or on the VALERI website: http://www.avignon.inra.fr/valeri).

[1] no dated

The LAI and fCover data are described in
Table 2:

Cell (see figure)	Easting (m) UTM 30 North, WGS-84	Northing (m) UTM 30 North, WGS-84	LAI LAI-2000 (m^2/m^2)	fCover LAI-2000 (%)
1	656011	1695593	1.13	12.2
2	656019	1694486	0.98	10.9
3	656025	1693579	0.91	10.3
4	655002	1695586	1.28	14.2
5	655009	1694590	1.27	13.9
6	655015	1693572	1.24	13.7
7	654022	1695579	1.16	12.4
8	654021	1694583	1.22	13.2
9	654028	1693566	1.17	12.6
		mean	*1.15*	*12.6*
		std	*0.12*	*1.3*

Table 2. Mean and standard deviation (std) values of the vegetation parameters for the 9 considered 1 x 1 km^2 cells.

LAI varies from 0.91 to 1.28 and fCover from 10.3% (0.103) to 14.2% (0.142). As the site is homogeneous in terms of LAI, the average value of the biophysical variables seems representative. Therefore, even if the production of high resolution, level 1, biophysical variable maps is not possible because of the sampling protocol, the average of biophysical variable values at the scale of the Gourma site is proposed.

Following, the results over the whole of Gourma site:

	LAI	fCover
Gourma site, 2001	1.15	0.126

Table 3. Average LAI and fCover values applied to the whole site for the two biophysical variables

3. Conclusion

The protocol sampling applied in 2001 was not allowing to produce high resolution, level 1, biophysical variable maps. However, the Gourma site is relatively homogeneous in terms of LAI. Moreover, the method used to estimate the biophysical variable values (LAI) at the scale of 1 x 1 km cells is consistent (annex or http://www.avignon.inra.fr/valeri). Therefore, the average biophysical variable values seem representative over the whole Gourma site. For more information, please read the campaign report which is very detailed.

4. Acknowledgements

We thank **Éric Mougin** (CESBIO), **Dembélé Fadiala** (IER), **Pierre Hiernaux** (ILRI).

ANNEX

VALERI-2001 CAMPAIGN IN GOURMA (MALI)

Participants:

Mougin Eric (CESBIO), Fadiala Dembélé (IER), Hiernaux Pierre (ILRI)

September 28 - October 6, 2001

VALERI-2001 CAMPAIGN IN GOURMA (MALI)

Due to administrative problems, it was not possible to reach the test site when the herbaceous cover was at its maximum of greenness that is by the end of August. The VALERI-2001 campaign only took place in the Gourma region at the beginning of the dry season from September 28 to October 6. At this date, the herbaceous layer was senescent since the last rainfalls were recorded 2 weeks earlier. Accordingly, measurements of the green foliage were not feasible. It means that neither LAI-meter measurements nor hemispherical photographs were acquired during this campaign. However, it was possible to use the sampling strategy that was developed during the 2000 campaign (*Mougin et al., 2000*) aimed at estimating the main vegetation characteristics : herbage mass, *LAI* and vegetation cover fraction *fcover*.

Description of the test site

The test site is located within the sahelian zone, in the Malian Gourma (Figure 1). The site corresponds to a 3 km x 3 km square whose the central co-ordinates is 15°19'23" N – 1°33'22" W. In this area, the landscape is characterised by gently undulating dunes with a sand content of about 90%.

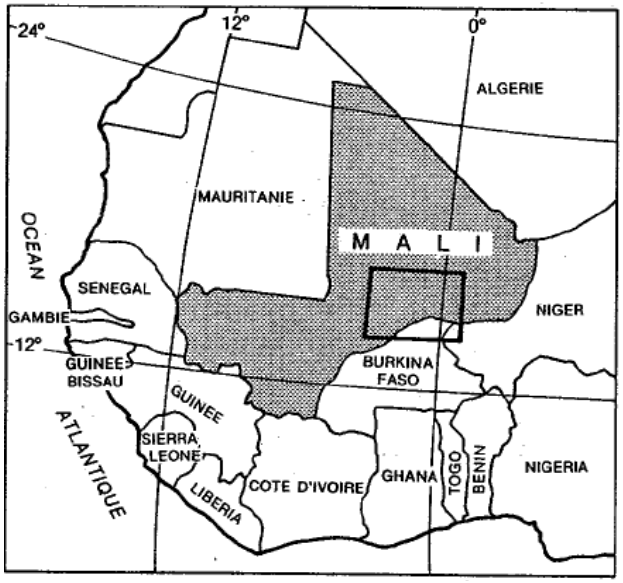

Figure 1: Localisation of the Gourma (Mali).

Within the test-site, the vegetation is usually sparse and principally composed of annual herbaceous species whose growth is mainly determined by the soil moisture regime which depends on the pattern of rainfall and on site geomorphology. Vegetation development starts after the first rains, in June or July, and unless the annual plants wilt before maturity by lack of rain, the senescence follows the fructification which matches with the end of the rainy season in September. The peak of the rainy season occurs in August. During the long dry season, there is no green vegetation apart from a few trees and shrubs.

Over the period 1984-2000, the mean annual rainfall is about 290 mm but is characterised by a strong interannual variation (Figure 2). The 1984 and 1999 years were the driest and the wettest seasons with a total amount of 95 mm and 582 mm, respectively. The 2001 rain season can be considered as an average year with a total amount of 310 mm close to the one measured during the 2000 season (292 mm).

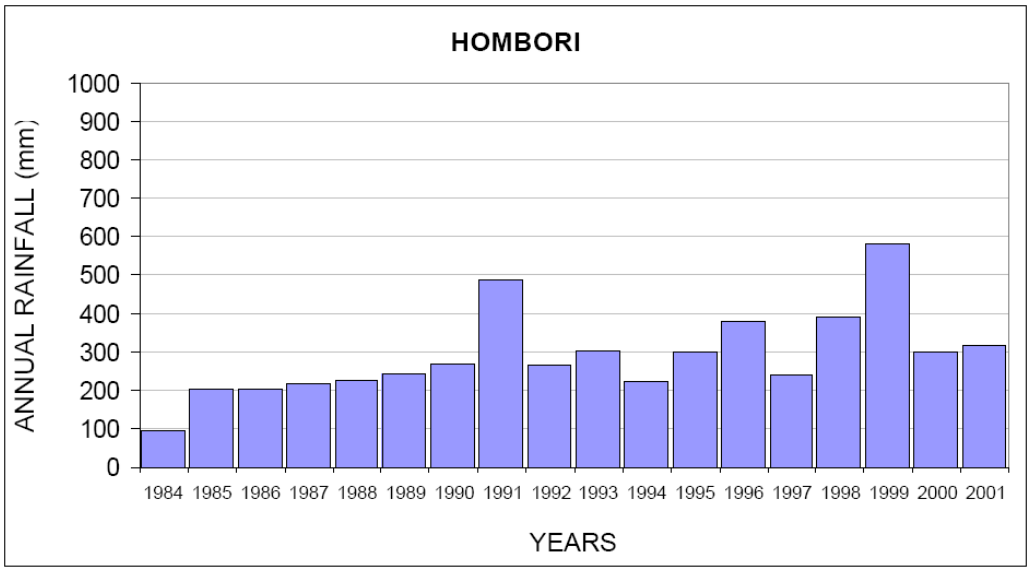

Figure 2: Interannual variation of the annual rainfall for the period 1984-2001. The data were acquired by the meteorological station of Hombori, located at a few kilometres from the VALERI site.

Similarly, changes in vegetation production accompany closely the interannual variation in rainfall. Over the period 1984-1999, the average herbaceous aboveground production, estimated by a measure at the end of the growing season, is about 99.4 g of dry matter per square meter (g DM m-2) with a coefficient of variation of about 44%. The corresponding maximum herbaceous cover fraction is about 11%. The herb layer is dominated by annual grasses (80% of the herb cover) with species such as *Aristida mutabilis*, *Cenchrus biflorus*, *Dactylotenium aegyptiaca*, *Tragus berteronianus* and *Schoenfeldia gracilis*. Besides, the average cover fraction of the woody plants canopy is smaller than 3%. Main tree species are *Leptadenia pyrotechnica*, *Acacia raddiana* and *Combretum glutinosum*.

The land surfaces of the Gourma consists of a mosaic of facets, each one characterised by distinctive combinations of landforms and soil types (*Diallo et al., 1999*). The soil type and the supply of moisture (mostly by rainfall) determine the edaphic conditions which are of crucial importance for plant growth. The selected VALERI test site is representative of vegetation formations on sandy soils which cover more than 50% of the whole Sahel.

Methodology

The overall methodology was described in the VALERI-2000 campaign report (*Mougin et al., 2000*). The following strategy was adopted :

a) Firstly, we used a SPOT image in combination with a morpho-pedology map of the whole area to delineate the main soil types and landforms. We then selected the 3x3 grid within a homogeneous zone exclusively located on sandy soils.

b) Secondly, we defined a 3 km x 3 km grid which was georeferenced and superimposed onto the SPOT image in the Geographical Information System 'ArcView'. Each of the 9 cells of 1 km square was then georeferenced and labelled as shown below.

7	4	1
8	5	2
9	6	3

Figure 3: Geometry of the 3 km x 3 km grid.

c) In each cell, we defined a sampling line of 1 km long and oriented along the North-South direction. In the field, the 9 sampling lines were positioned with the help of a GPS. The corresponding co-ordinates are given in Annex 1. Observations and measurements were performed along the 9 sampling lines during the VALERI campaign.

d) Finally, we assumed the sampling line to be representative of the corresponding cell and we attributed the estimated mean and variance values to this cell.

Sampling strategy

Only the characteristics of the herb layer were measured during the 2001 campaign. Along the sampling line, the following parameters were estimated using a two level stratified random technique (*Hiernaux, 1992*):
- Above-ground herbage mass, *Bm* (g DM m^{-2})
- Vegetation cover fraction, *fcover* (%)
- Leaf Area Index, *LAI* (m^2 m^{-2})

The stratification of the site includes the following steps: a) Major differences in vegetation induced by terrain features were identified as facies sampled individually. b) Within each facies, four strata were systematically distinguished every meter on the basis of the apparent density of the herbaceous layer that is bare soil, and relatively low, medium and high density.

For each considered parameter, measurements were performed within 12 quadrats of 1 m x 1 m that were randomly positioned along the sampling line in order to get 3, 6 and 3 samples in the low, medium and high density stratum, respectively. In each quadrat, the floristic composition is noted, the vegetation cover fraction is visually estimated and the aboveground herbage mass is weighted after total clearance cutting and drying.

Along a sampling line, the mean value of a given parameter calculated for a given stratum is then weighted by the relative importance of the 4 strata and facies identified along the sampling line to get the estimated mean X :

$$X = \sum_{i}^{n} (p_i \, . \, x_i)$$

Where *pi*, *xi* and *n* denotes the relative frequency of the stratum *i*, the mean value of the parameter measured for the stratum *i* and the total number of strata (n = 4). The associated variance is calculated as (*Cook and Stubbendieck, 1987*):

$$Var(X) = \sum_{i}^{n}[\ p_i\ .(s_i^2 / n_i)\ ]\ \ +\ \ 1/\ [\ \sum_{i}^{n} P_i\ ].[\ \sum_{i}^{n}(p_i\ .x_i^2) - x^2\ ]$$

Where s_i^2, n_i and P_i are the variance of the considered parameter, the number of samples in the stratum *i* and the absolute frequency of the stratum *i*, respectively.

Results

As indicated before, field measurements were carried out when the herbage layer was senescent just following peak mass. Accordingly, these measurements can provide an accurate estimation of the vegetation status around peak mass which occurred during DOY 243-253 (September 1-10).

1) Herbage standing mass Bm

For the 9 considered cells, the mean *herbage mass* is about 157.5 g DM m-2 which is twice the value found in 2000 (72.8 g DM m-2). In order to check the robustness of the selected methodology, we repeated twice the same sampling strategy over the cell #1 on September 28 and on October 3, respectively. Results show that the two estimations are not significantly different (158.4 g DM m-2 compared to 154.1 g DM m-2) with a difference smaller than 3%.

2) Vegetation Cover Fraction f_{cover}

Only a visual estimation of the *vegetation cover fraction* was done. This parameter ranges from 10.3% to 14.2% with a mean value of 12.6% (10.5% in 2000).

3) Leaf Area Index LAI

The *LAI* was estimated from *herbage mass* (*Bm*) and *Specific Leaf Area* (*SLA*) measurements (see 2001 report). The resulting mean values for the 3 strata were then weighted by the respective cover fraction of each stratum to obtain the estimated *LAI* along a given sampling line.

The *LAI* is simply calculated as :

LAI ($m^2\ m^{-2}$) = *Bm* (g DM m^{-2}) . *SLA* ($m^2\ g^{-1}$ DM)

The Specific Leaf Area, *SLA*, for the dominant herb and grass species was estimated during the 2000 campaign. Here, we used the same mean *SLA* values for herb and grass, respectively. The grass cover fraction was estimated to 87% in 2001 compared to 84% in 2000.

Estimated *LAI* range from 0.91 to 1.28 with a mean value of 1.13 $m^2\ m^{-2}$.

Table I gives a synthesis of the 3 main vegetation parameters that were estimated at the scale of a 1-km long sampling line (and therefore at the scale of a 1km x 1 km cell).

Cell #	*Herbage Mass* (g DM / m^2)	f_{cover} (%)	*LAI* (m² / m²)
1	154.1 (5.6)	12.2	1.13 (0.12)
2	133.1 (5.2)	10.9	0.98 (0.10)
3	124.5 (5.4)	10.3	0.91 (0.10)
4	175.9 (6.6)	14.2	1.28 (0.14)
5	174.0 (6.5)	13.9	1.27 (0.14)
6	170.0 (6.3)	13.7	1.24 (0.14)
7	158.9 (5.7)	12.4	1.16 (0.12)
8	166.4 (6.0)	13.2	1.22 (0.13)
9	160.7 (5.8)	12.6	1.17 (0.13)
Mean	**157.5 (6.0)**	**12.6 (1.3)**	**1.15 (0.13)**

Table I: Estimated mean and standard deviation values of the vegetation parameters for the 9 *fcover and LAI* are corrected values taking into account the decrease of herbage mass since the peak of standing mass.**

Conclusion

The VALERI-2001 campaign took place at the end of the growing season when the herbaceous layer was senescent. Although no measurement on the green foliage has been made, the three following vegetation parameters have been accurately estimated : standing mass, vegetation cover and *LAI*. We can reasonably assume that these values are also valid for the period September 1-10, when the vegetation cover was at its maximum of greenness. This period can be retained for a comparison with satellite derived parameters.

References

. Cook and Stubbendieck, 1987, Range Research: Basic Problems and Techniques. Edited by the Society for Range Management.
. Diallo et al., 1999, Morpho-pédologie du Gourma. Programme de Recherche SSE, 19p.
. Hiernaux P., de Leeuw P.N. et Diarra L., 1992, Dynamique de la végétation sahélienne après sécheresse. Un bilan du suivi des sites pastoraux du Gourma en 1991. Document de travail

Annex 1

Co-ordinates of the 2001 sampling lines.

Line Number	Latitude (N)	Longitude (W)
1	15°20'12" - 15°19'40"	1°32'48"
2	15°19'40" - 15°19'07"	1°32'48"
3	15°19'07" - 15°18'34"	1°32'48"
4	15°20'12" - 15°19'40"	1°33'22"
5	15°19'40" - 15°19'07"	1°33'22"
6	15°19'07" - 15°18'34"	1°33'22"
7	15°20'12" - 15°19'40"	1°33'55"
8	15°19'40" - 15°19'07"	1°33'55"
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