



## **Towards an Operational GMES Land Monitoring Core Service**

### **BioPar Product User Manual HR Biophysical Products**

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## 1 BACKGROUND OF THE DOCUMENT

### 1.1 EXECUTIVE SUMMARY

Within the frame of geoland2 BioPar Core Mapping Service, a comprehensive set of HR biophysical products is to be generated on on-demand basis, on selected geoland2 test sites. The typical objective is to obtain this biophysical information at 3 dates along a growing season in order to perform a monitoring of the vegetation that will serve to produce a thematic classification or to derive application-specific information.

This document is the Product User Manual of these BioPar HR products.

### 1.2 SCOPE AND OBJECTIVES

The document provides an overall description of the BioPar HR products, allowing the User to understand the product content, the way it is produced, its strength and limitations, and providing all product format information to be properly handled.

### 1.3 CONTENT OF THE DOCUMENT

This document is structured as follows:

Chapter 2 first gives a review of the produced biophysical parameters, and then presents the retrieval methodology, with a discussion of error sources and products limitations.

Chapter 3 provides an overall description of the product in term of file format, product content and summary of product characteristics.

Chapter 4 presents validation results attached to the product.

### 1.4 RELATED DOCUMENTS

#### 1.4.1 Input

Overview of former deliverables acting as inputs to this document.

<b>Document ID</b>	<b>Descriptor</b>
BP-RP-BP011	User Requirements Document
BP-RP-BP012	Service Specifications Document
BP-RP-PP022	Validation Report of High Resolution Vegetation Parameters (g2-BP-RP-BP022-ValidationReport-HRProducts-I1.00)

## **1.4.2 Output**

Overview of other deliverables for which this document is an input.

<b>Document ID</b>	<b>Descriptor</b>
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## 2 ALGORITHM

### 2.1 PRODUCT OVERVIEW

The product package provided in the BioPar BP-11 product is produced from HR sensor data and contains the following biophysical parameters:

#### 2.1.1 Fraction of vegetation cover (FCover)

FCover is a classical parameter produced from remote sensing. It is used to separate vegetation and soil in energy balance processes, including temperature and evapo-transpiration. Most of the time, it only refers to the green part of the vegetation canopy. This definition is kept here, i.e. this is the cover of green vegetation, and it is estimated in a vertical direction (downward looking), independently of the actual sensor image viewing or illumination conditions. So this can be described as the % of HR pixel covered by green vegetation if it were viewed vertically.

#### 2.1.2 Fraction of brown vegetation cover (FBrown)

FBrown is similar to the FCover, but refers to the brown part of the vegetation – or non photosynthetic vegetation (NPV) –. Whereas green vegetation is mainly composed of green leaves, the NPV is rather variable in nature, structure and colour: senescent crops, dry grasslands, crop residues, branches and tree trunks, dry understorey, etc.

As for the FCover, the FBrown is provided in a normalised direction which is the vertical downward looking (nadir) direction.

#### 2.1.3 Leaf Area Index (LAI)

LAI is defined as half the developed area of leaves of the vegetation per unit horizontal ground area. It determines the size of the interface for exchange of energy (including radiation) and mass between the canopy and the atmosphere. This is an intrinsic canopy primary variable.

Note that in this definition, LAI will refer to the whole foliage and not only the photosynthetically active elements of the vegetation, i.e. it will de facto also include the NPV component. It is however rather straightforward to get the **Green LAI (GLAI)** – the LAI that corresponds only to the photosynthetically active part of the foliage – with the following formula:

$$GLAI = LAI \times \text{green ratio}, \text{ where } \text{green ratio} = F_{Cover} / [F_{Cover} + F_{Brown}].$$

LAI was originally defined for flat, regular canopies like crops or grasslands, as a core parameter to describe vegetation density and to develop reflectance models of the canopy. The use of LAI was then extended to any type of vegetation.

At the size of the HR pixel, the vegetation is assumed homogeneous.

The model from which LAI is derived also assumes a random distribution of leaves in the canopy. If at local scale there is systematic aggregation of leaves (or leaf "clumping"), this is not retrieved from remote sensing and so the produced LAI is rather an "effective" LAI, corresponding to the one with random distribution producing same signal.

#### 2.1.4 FAPAR

The FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) is a widely used parameter, serving as input to a number of primary productivity models based on simple efficiency considerations.

This parameter normally corresponds to the daily integrated FAPAR value, and actually depends whether there are clear sky or diffuse light conditions. In the current product, this is in fact approached by the estimation of FAPAR at the time of the satellite overpass, which is most HR sensors around 10:00 am local time; a recent study [1] showed that these conditions were indeed very close to the daily integrated value under clear sky conditions.

#### 2.1.5 Fraction of Soil (FSoil)

As for the other fraction parameters, FSoil represents the fraction of soil that is visible in vertical direction, whether this correspond to bare soil patches or holes in developed canopies ("gap fraction"), sunlit or shaded from the canopy.

So this is the complementary fraction to the vegetation cover fractions, and in the absence of water or snow it is simply expressed as:  $F_{Soil} = 1 - (F_{Cover} + F_{Brown})$

#### 2.1.6 Chlorophyll (Chl)

Chlorophyll represents the content of chlorophyll of both a/b types (Chla + Chlb) in the green leaves of the vegetation cover, expressed as pigment content per unit surface of leaves, in  $\mu\text{g}/\text{cm}^2$ . This parameter is an input variable to the leaf model used in the retrieval algorithm (PROSPECT) and an intrinsic measurement of the greenness of the vegetation, and is used as an indicator of nitrogen nutrition or general plant health in many agriculture and forestry applications. The chlorophyll level will differ according to plant species, and for a given plant type there is significant evolution of the leaf chlorophyll along the leaf cycle.

Nominal range of chlorophyll content (for green leaves) is from 20 to 120  $\mu\text{g}/\text{cm}^2$ .

Important notice: the Chl product shall not be confused with the **Canopy Chlorophyll Content** that is the overall amount of chlorophyll per ground unit area and can be expressed as the multiplication of Leaf Area Index (of green leaves) by the chlorophyll content of the leaves (Chl). Some applications sometimes refer to this alternative way of providing the chlorophyll information; it can be obtained from the current set of products by the following computation:

$$\text{Canopy CHL} = \text{GLAI} \times \text{Chl} \quad (\text{where } \text{GLAI} = \text{LAI} \times \text{FCover} / [\text{FCover} + \text{FBrown}] )$$

### 2.1.7 Canopy Shade Factor (CSF)

Vegetation types like crops and grasslands have mostly flat and regular canopies. Vegetation like trees and shrubs have an irregular canopy surface with many cast shadows that create a much darker canopy and this is very visible in remote sensing images. This characteristic is here described by the Canopy Shadow Factor, which quantifies the fraction of canopy surface that is under shadow.

Flat canopies will have a CSF value close to 0, whereas forest canopies can have CSF ranging typically from 0.4 to 0.85 (i.e. 40 to 85% of shadowed canopy), depending on the forest type and age.

It is to be noted that CSF is not a true absolute characterisation of the canopy, as it will depend also on the image directional conditions, both viewing and Sun directions. Highest CSF values will correspond to either thick cloud cast shadows or topographic shadows and will be normally quality flagged.

### 2.1.8 Fraction of Water (FWater)

Beyond the vegetation and soil parameters, the HR products package aims to provide characterisation of other natural elements when detected. In a similar way to the FCover, the FWater parameter marks the presence of water and indicates the fraction of the HR pixel that is covered by water.

Water bodies that are detected may show a variety of water colour and quality, from blue pristine waters to green, brown or highly turbid waters. Some partial water conditions – in particular those involving dark waters – may be highly ambiguous with dark shaded vegetation. In the provided product, this will be warned with a specific "confusion risk" quality flag.

### 2.1.9 Fraction of Snow (FSnow)

With a similar objective to complement the vegetation parameters, and of interest in particular to the Alpine and Northern Europe countries, the FSnow parameter indicates the fraction of the HR pixel that is covered by snow, when snow is present.

## 2.2 SENSOR SOURCES

The BP-11 parameters are intended to be generated from different HR sensor sources, and as far as possible to provide information that is independent from the sensor. This may be however be limited by the fact that the sensors have different richness in terms of spectral information, and as a result some parameters may be not accessible or present a lower accuracy performance.

This is further discussed in §2.4.2

In the frame of the geoland2 project, according to the DAP requirements document the HR data may come from various sensor sources procured by ESA. For the first acquisition year of the project, the following sensors were actually used:

- SPOT (SPOT5, SPOT4 and SPOT2)
- Rapid-Eye
- IIRS-P6 LISS3 and AWIFS

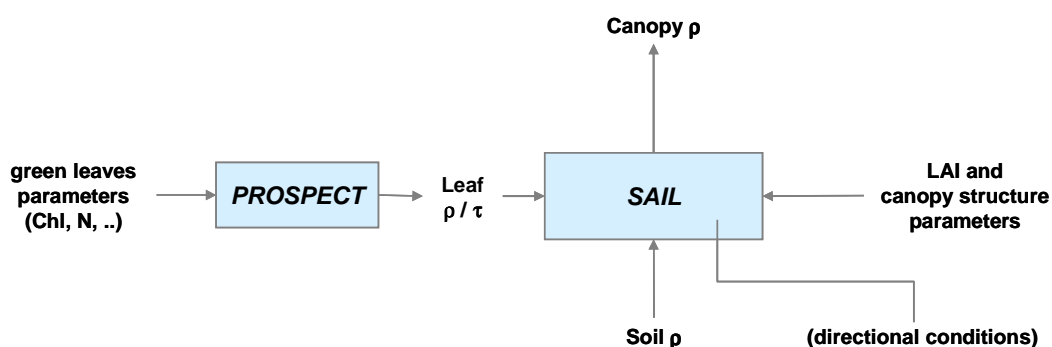
The BioPar HR processing line is indeed designed so as to be able in principle to process any sensor data in the VNIR/SWIR domain.<sup>1</sup>

## 2.3 RETRIEVAL METHODOLOGY

All BP-11 parameters are estimated through the use of reflectance models for the vegetation, and performing overall inversion of the model being designed. Produced parameters are either entry variables to these models, or information that is derived in the stream of model computations.

### 2.3.1 Modelling principles

The baseline vegetation model developed for processing the HR data uses the SAIL/PROSPECT model as core component [10][11] (Figure 1). Among existing radiative transfer models to simulate canopy reflectance, SAIL was found one of the most attractive models for its overall performance [4]. PROSPECT is a generic model of the leaf optical properties [3]. The SAIL/PROSPECT association has been widely used and validated by the scientific community since more than 15 years now [5]. It was initially designed for green, homogeneous and regular canopies, like crops or grasslands.



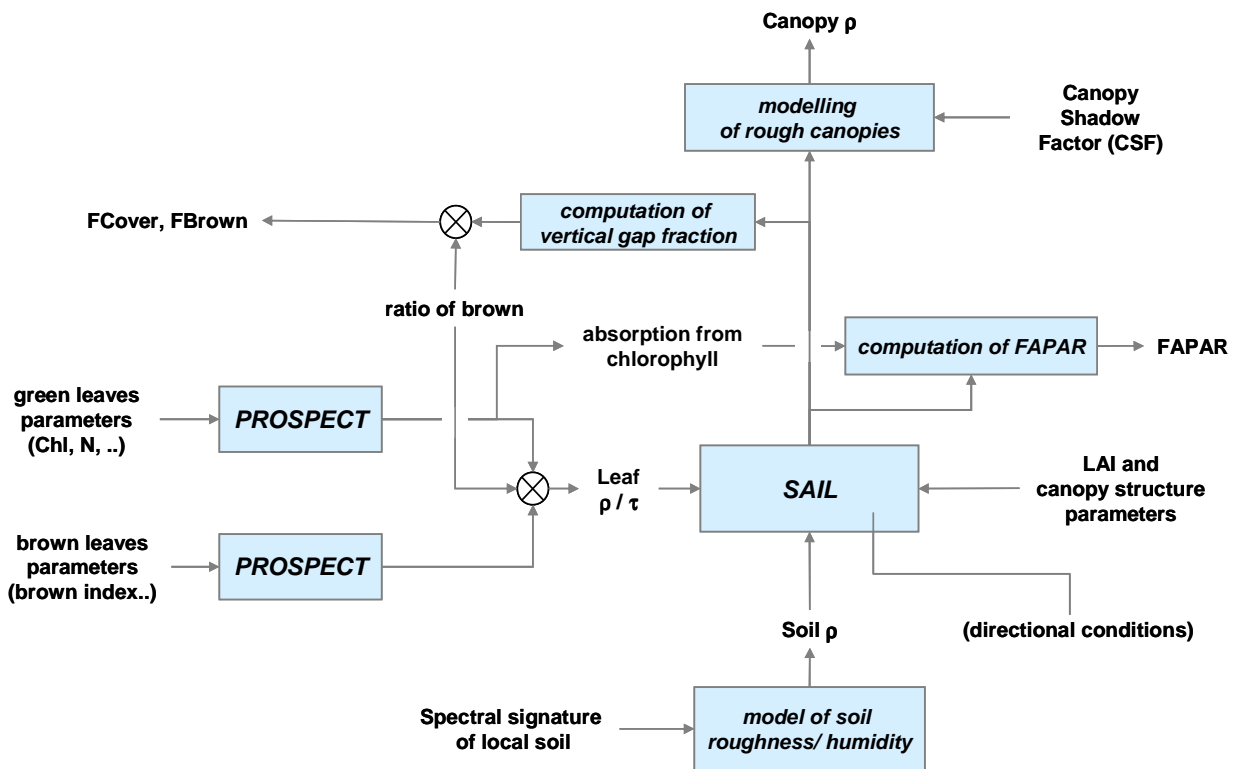
**Figure 1 – Principle of the SAIL/ PROSPECT model**

SAIL computes the canopy reflectance ( $\rho$ ) from the reflectance/ transmittance ( $\rho/\tau$ ) of the leaves provided by PROSPECT plus the data of the soil reflectance

<sup>1</sup> In addition to the sensors quoted above, the list of sensors already interfaced in the HR processing line includes: Landsat (TM or ETM), Formosat-2, QuickBird, IKONOS, ALOS-AVNIR2, DMC / DMC 2, THEOS.

In our case, this model was upgraded and completed in order to include (Figure 2):

- the contribution of brown (or NPV) vegetation:  
In addition to the leaf optical properties provided with the PROSPECT model and applicable to green leaves, characterisation of the so called "brown pigments" that produce brown vegetation was obtained from various dry vegetation material. The model combining green and brown vegetation is single layer and considers an homogeneous mixture of green and brown leaves, each leaf type (i.e. green or brown) having separate PROSPECT variables description.
- the modelling of "rough" canopies:  
As already indicated, the SAIL/PROSPECT was initially designed for crops and is unable to simulate the dark response of forest and shrub canopies. The addition of a surface shadow model, controlled by the Canopy Shadow Factor (CSF) is a simple way to introduce mutual shadow effects over the canopy surface layer, like in geometrical-optical models.
- the computation of vegetation cover fractions in reference directional conditions:  
In addition to the two specific directions (the sensor viewing and the Sun illumination directions) that are processed in the 4-stream formalism of the SAIL model, gap fraction computations are also systematically performed in a 3<sup>rd</sup> direction that is vertical, downward looking, defined as the normalized direction to provide vegetation cover fractions.  
By considering the respective contributions of green and brown vegetation, this then allows to derive the FCover and the FBrown parameters.
- the computation of FAPAR from the SAIL model:  
Formal computation of FAPAR has been added to the SAIL model, considering both cases of direct illumination (at the time of image acquisition) and diffuse light, and performing weighted average corresponding to standard sky conditions. In both cases, FAPAR is computed from the data of canopy interception, absorption linked to chlorophyll in the domain 0.4–0.7  $\mu$ , and the contribution of diffuse light reflected from the underlying soil in the overall canopy chlorophyll absorption.



**Figure 2 – Diagram of the generic vegetation model based on SAIL/PROSPECT (homogeneous case)** with separate modelling of green and brown leaves, additional computation of fraction cover and FAPAR, and modelling of rough canopies

Another important component of the developed model is the soil modelling, the soil reflectance being an input to the SAIL model. In fact, even at local scale soils may show a large range of variability, in particular variation of the soil "brightness" in relation with soil roughness and humidity. In the present case, this is handled by performing an initial learning of the soil mean spectral signature in the sensor spectral domain, at a regional level. Then this signature will be exploited through a physical model of soil variability, accounting for the soil shading and surface humidity effects.

This scene model is then coupled with a model of the atmospheric transmission from Earth surface level to the sensor. The developed solution is very much similar to the one described in [12]: it is based on the LOWTRAN model [6] [9] and performs preliminary calls of this model to generate Look-Up-Tables (LUTs) for the considered image directional conditions. This allows describing the variation of transfer function of the atmosphere as mainly dependent on two variables, in the VNIR domain: the aerosols load and the water vapour column. In order to take care of the clouds, an additional cloud model is plugged to this atmospheric model; the potential cloud layer is described as a turbid medium of mostly white scattering elements (absorption being mostly limited to cloud

liquid water). The layer thickness is controlled by the corresponding optical depth, the output information from this model used to assess observation quality being the *cloud apparent reflectance*. Typically, a cloud reflectance value in the range [0.05 – 0.07] is used as quality threshold, this corresponding to a optical thickness of ~ 0.6.

### 2.3.2 Model inversion and parameters mapping

The HR image pixel value is initially transformed into Top of Atmosphere (TOA) reflectance  $\rho^0$ .

Retrieval of the biophysical parameters consists in finding the best estimate  $\hat{v}$  of input variables to the reflectance model  $M(v)$  that will agree with measured reflectance  $\rho^0$ , i.e.:

$$\rho(M(\hat{v})) \approx \rho^0 \quad \rho(M(v)) \text{ is further noted simply } \rho(v)$$

Inversion of such a model is known to be an-ill posed problem due to the large number of input variables and to the great variability of model sensitivity to these different variables. In order to get robust and smooth behaviour of the model inversion process, there is used a “cost function” to minimize that is made of two terms, the first term represents the distance between measured and modelled TOA reflectance while the second term computes the distance of the variables estimates to central values of these variables, according to a-priori statistics on model variables. This term achieves the so-called regularisation of the inversion process.

### 2.3.3 Additional models for water and snow

Additional models can be plugged-in to the standard land model in order to perform the specific detection of water bodies and snow covers (to generate the FWater and FSnow products). These two dedicated models have the following characteristics:

- The water model is of the Case-2 Water type (i.e. including contribution from the water bed in shallow water conditions) and is implemented using the 4-stream formalism of the SAIL model. It takes into account coloured dissolved organic matter (CDOM) and chlorophyll (phytoplankton) absorption to be able to simulate both brown and green water conditions.
- The snow model is a model of opaque surface with the optical properties of snow; the spectral shape is mainly controlled by the snow grain size, which is indeed linked to the surface humidity / temperature of the snow surface.

### 2.3.4 Synthesis of biophysical maps

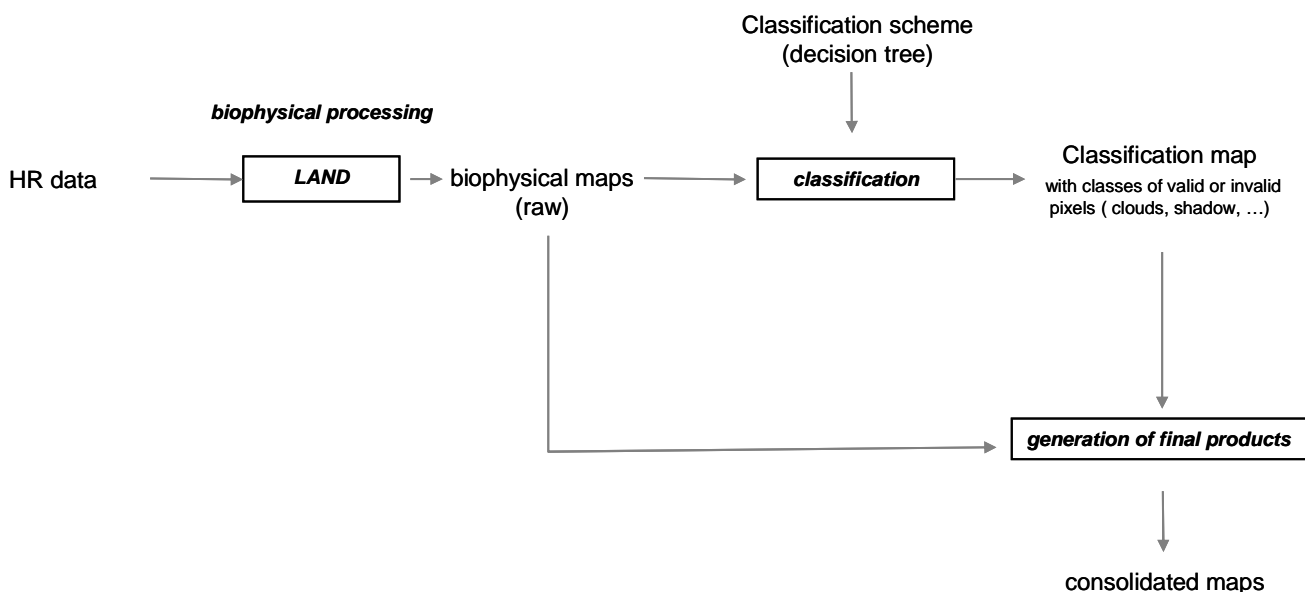
Depending on user demand, the HR image can be processed with a single “theme”, *LAND*, corresponding to the standard vegetation model aiming to provide all vegetation parameters, or processed with several themes, that are, in addition to *LAND* :

- *WATER*, with the additional water model in order to map water bodies,
- and *SNOW*, to detect snow cover conditions (when relevant)

Then an automated classification is performed to identify degraded conditions cases (e.g. clouds, dark shadows or water, bad pixels) and produce the set of biophysical maps with the corresponding quality flags.

Below is first presented the case with a single theme processing (Figure 3). The associated table (Table 1) defines the rules for the provision of the biophysical parameters with the relevant quality flags. Clouds/haze and dark shadows/water conditions are identified by appropriate criteria on the produced raw biophysical layers, and this generates the corresponding *SHADOW* and *CLOUDS* quality flags. The *BAD PIXEL* quality flag indicates pixels for which there was detected a bad agreement between HR data and the reflectance models (likely some non natural surfaces, or local failure to converge of the inversion process).

**Important note:** For the first delivery of HR products generated with the single *LAND* processing, for simplicity of use all pixels of clouds, cloud shadows or water were classified as "Bad Pixels". As a result they will all get the *BAD PIXEL* quality flag.



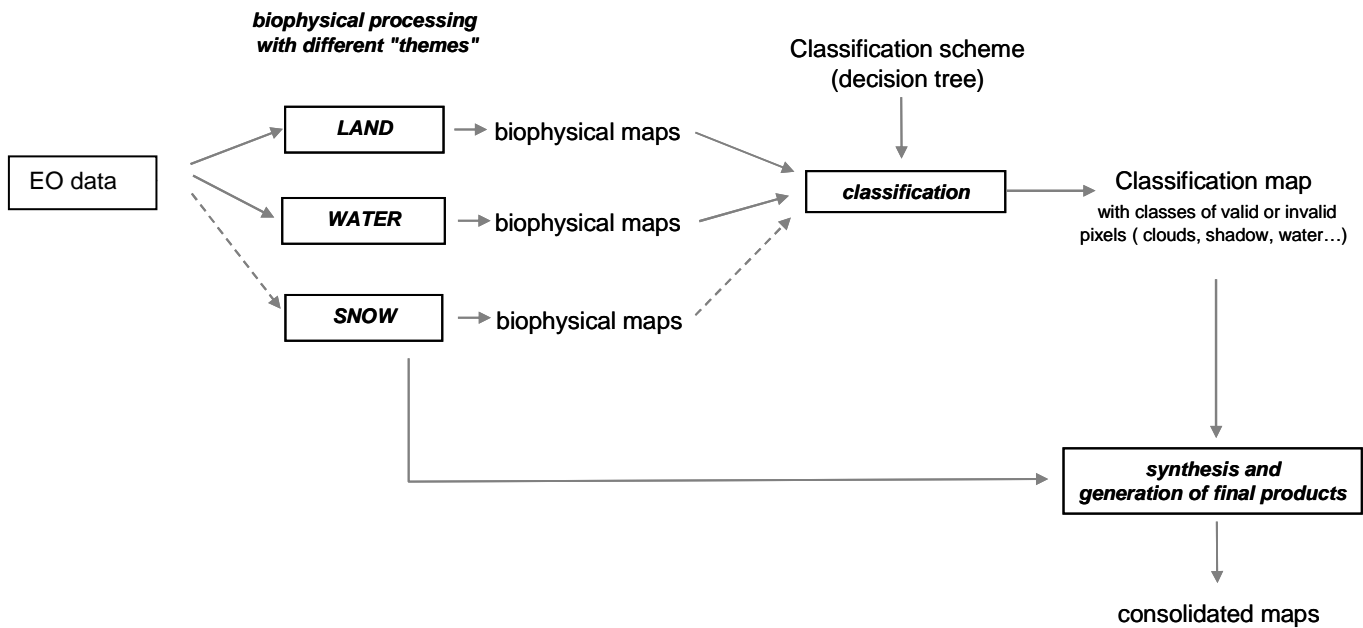
**Figure 3 – Mechanism for quality flag generation (single *LAND* processing)**

Class	Biophysical Variables							Quality Flags						
	Selected Theme	FCOVER	FBROWN	FSOIL	FAPAR	LAI	CHL	CSF	SHADOW	CLOUDS	not used	not used	CONFUSION	BAD PIXEL
Land	LAND	✓	✓	✓	✓	✓	✓	✓						
Dark shadows									1					
Clouds									1					
Bad Pixels													1	

**Table 1 : Production rules from the classification (single LAND processing)**

*Indication of the parameters provided and flags set for each class*

Then the case with multiple processing is illustrated (Figure 4), with the table of related production rules for the biophysical maps (**Erreur ! Source du renvoi introuvable.**)



**Figure 4 – Case of multiple processing to determine water and snow conditions**

Class	Selected Theme	Biophysical Variables										Quality Flags					
		FCOVER	FBROWN	FSOIL	FAPAR	LAI	CHL	CSH	FWATER	FSNOW	SHADOW	CLOUDS	WATER	SNOW	CONFUSION	BAD PIXEL	
Land	LAND	✓	✓	✓	✓	✓	✓	✓									
Water	WATER							✓				1					
Water / Dark shadows	WATER							✓			1	1		1			
Dark shadows											1						
Clouds												1					
Clouds / Snow	SNOW								✓			1		1	1		
Snow	SNOW							✓					1				
Bad Pixels																1	

**Table 2 : Production rules from the classification (case of multiples themes processing)**  
*Indication of the parameters provided and flags set for each class*

## 2.4 ERROR ESTIMATES

### 2.4.1 Sources of error

The error sources can be broadly divided into two categories

- A first error source relates to the actual performance and accuracy of the model, here primarily the ability of the core SAIL/PROSPECT model to properly simulate vegetation canopies
- A second error term relates to the capability to retrieve the target parameters from the sensor data, depending on sensor spectral richness and data radiometric quality.

Concerning the applicability of the SAIL/PROSPECT model, there is a number of scientific references about its test use and validation for different crops and other vegetation canopies [5]. From 1996 to 2000, Infoterra France (at that time in the EO application group of Matra Marconi Space) regularly conducted their own ground validation campaigns in Europe and America, with airborne CASI data (with a super-spectral VNIR configuration), in order to verify LAI and chlorophyll estimation performance for a variety of crops (corn, wheat, soybean, sugar beet, ...). ([1], [2], [7], and [8]). It must be noted however that the SAIL/PROSPECT performance is not so well documented for conditions of NPV, and that this model alone cannot fully simulate conditions of rough vegetation with significant self-cast canopy shadows. This is the reason for the addition of a geometric model (controlled by the CSF variable) to the SAIL optical model.

Considering the sensor-related level of performance, this performance can indeed be theoretically assessed by model simulations and through the model inversion process, taking into account the characteristics from the sensor<sup>2</sup>. The next sections will present this aspect, and will discuss the expected performance depending on the HR sensor used.

### 2.4.2 Assessment of the sensor-related errors

The sensor data characteristics will affect the retrieval performance in the following way:

- capability to retrieve parameters depends on the ability to discriminate their respective effects thanks to set of spectral bands provided by the sensor; some sensors may just not be appropriate to get access to some parameters if they miss some critical spectral domain.
- sensor data of lower radiometric performance will result in both increased noise and reduced sensitivity for the most demanding parameters

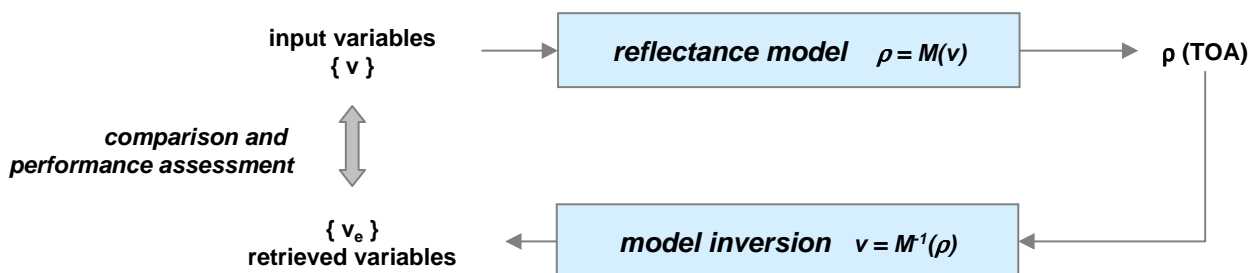
The intrinsic performance can be assessed with the following procedure:

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<sup>2</sup> The underlying assumption is that model is close enough to reality so that data sensitivity and the related retrieval performance can be properly assessed

- an experimental design defines a number of model reference cases, or range of variation of the different input variables, in order to test the performance and robustness of the process
- the corresponding reflectance values are computed from the model
- they are then inverted with the defined inversion algorithm and deviation from their original values are analysed

This procedure is illustrated on Figure 5 below.



**Figure 5 – Procedure for assessing achievable performance of the inversion process for a given reflectance model and a given sensor configuration**

As the spectral configuration has a significant impact on the parameters retrieval performance<sup>3</sup>, we propose to group the existing HR sensors into the following sensor classes:

- **SPOT-like** (green, red, NIR and SWIR bands) : SPOT-4, SPOT-5, IRS-P6 AWIFS and LISS3
- **SPOT without SWIR** : SPOT-2, DMC, DMC-2
- **VNIR4** (blue, green, red, and NIR bands): Formosat-2, QuickBird, IKONOS, ALOS, THEOS, etc.
- **VNIR5** (same bands plus Red-Edge band): RapidEye
- **Landsat** (4 VNIR bands plus SWIR1 /SWIR2 bands) : Landsat 4-5 TM, Landsat 7 ETM

The next sections present the results obtained for the two sensor classes used up to now to generate the BioPar HR products, that is the SPOT and VNIR5 classes.

<sup>3</sup> In the same time, it is highly desirable that some key biophysical parameters – e.g. FCover, FAPAR, etc – can be obtained with acceptable performance from a majority of sensors such that they can be produced on large areas from a mosaic of images from the different sensors.

### 2.4.3 SPOT class error estimates

The SPOT class SPOT is the dominant spectral class for the source data of BioPar HR products (applicable to SPOT, LISS3 and AWIFS). The following figures illustrate some key performance results obtained with the procedure described above (Figure 6 to Figure 10).

Major outputs of this analysis are:

- FCover and FAPAR are the most robust parameters
- LAI estimation is sensitive to the foliage type (broad leaves or thin erected leaves) and chlorophyll level that are not properly retrieved
- There is good restitution of canopy roughness conditions through the CSF parameter
- The NPV dominant conditions can be correctly retrieved through the FBrown parameter, however there is an error level much larger than of the green vegetation (in fact there is some regional effect as this will be dependent on contrast between NPV and local soil)
- There is some sensitivity to Chlorophyll once canopy closure is reached, however there remains some strong coupling with other model variables, and there may be some significant bias from one image to the other.

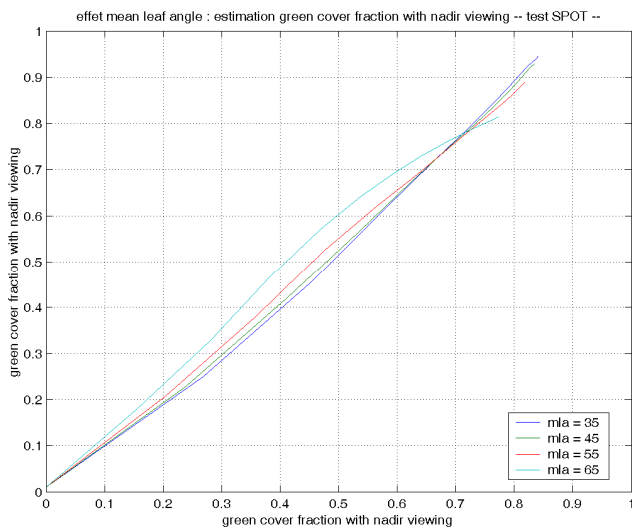
As a synthesis of the results, we propose the following range for error estimates (RMS) for the SPOT-like sensor spectral class<sup>4</sup>:

- FCover : 3 – 5 %
- FAPAR : 3 – 5%
- LAI : 20 – 35% (*relative error*)
- Chlorophyll : 10 – 15  $\mu\text{g}/\text{cm}^2$

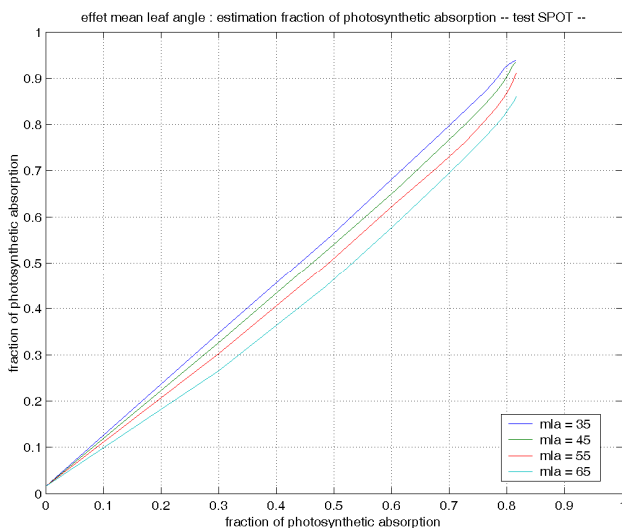
Due to its rather low performance, unless specifically requested the Chlorophyll product will not be delivered.

---

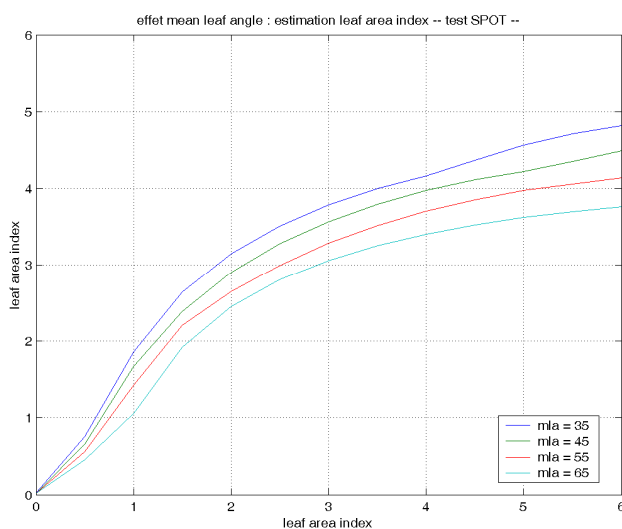
<sup>4</sup> These performances are obtained without a prior knowledge on the canopy type, i.e. a fully generic vegetation model is applied to generate the BioPar HR products. Clearly, higher performances can be reached by the proper parameterization of the model for a given vegetation type (e.g. a given crop) , for dedicated applications.



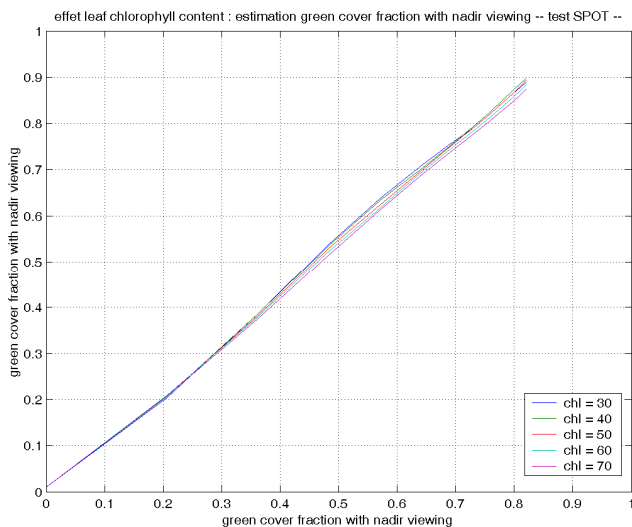
**Figure 6 –  
 Sensitivity to  
 foliage structure  
 (SPOT class)  
 mean foliage angle  
 from 35° to 65°  
 retrieved FCover (y)  
 versus actual  
 FCover (x)**



**retrieved FAPAR (y)  
 versus actual  
 FAPAR (x)**



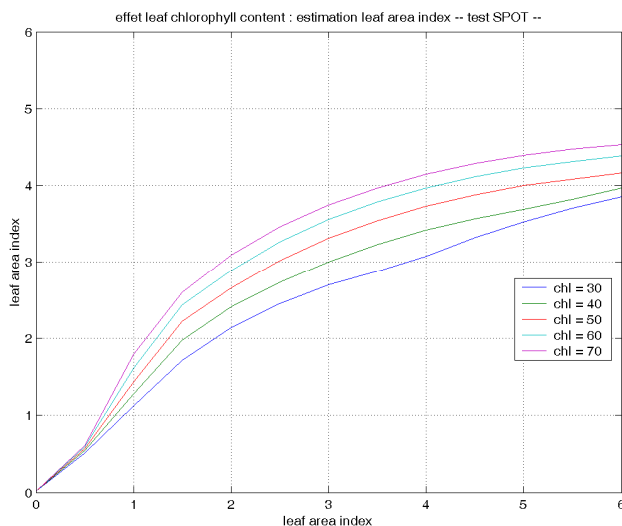
**retrieved LAI (y)  
 versus actual LAI  
 (x)**



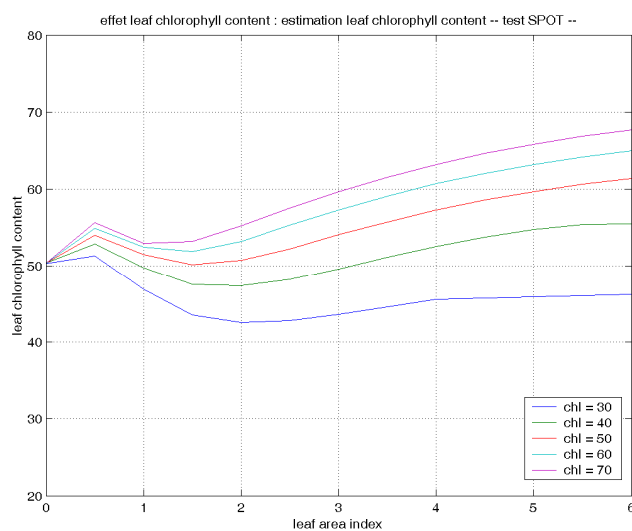
**Figure 7 – Sensitivity to chlorophyll (SPOT class)**

*chlorophyll from 30 to 70  $\mu\text{g}/\text{cm}^2$*

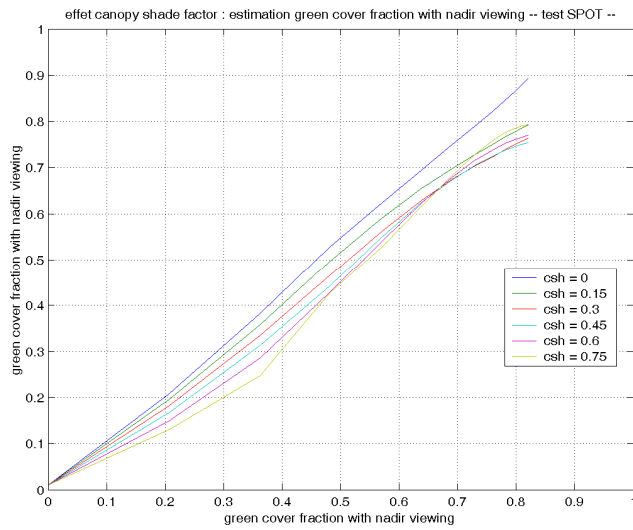
**retrieved FCover(y) versus actual FCover (x)**



**retrieved LAI (y) versus actual LAI (x)**



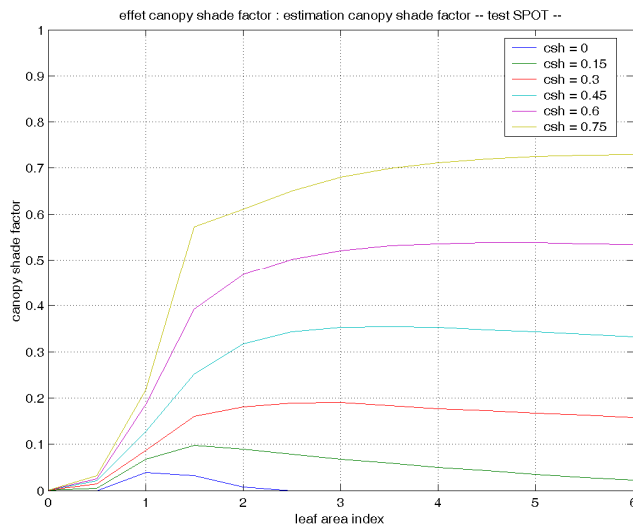
**retrieved Chlorophyll (y) as a function of LAI (x)**



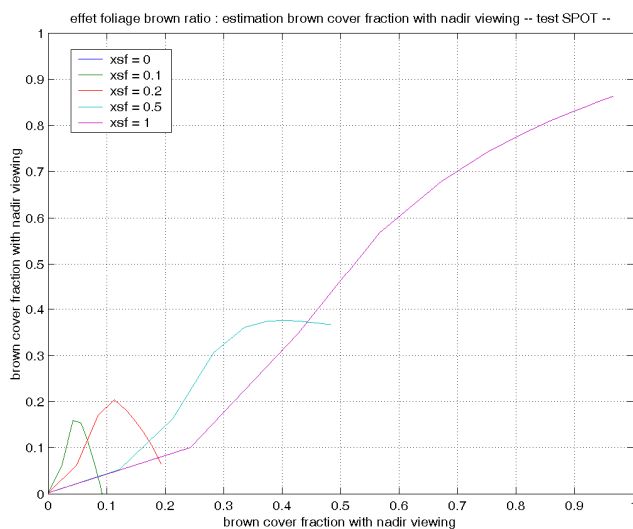
**Figure 8 – Sensitivity to canopy roughness (SPOT class)**

*CSF from 0 to 0.75*

**retrieved FCover (y) versus actual FCover (x)**



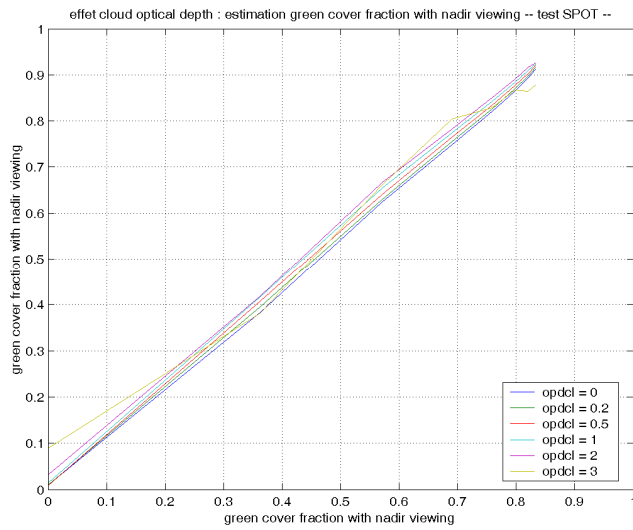
**retrieved CSF (y) as a function of LAI (x)**



**Figure 9 – Sensitivity to non photosynthetic vegetation (SPOT class)**

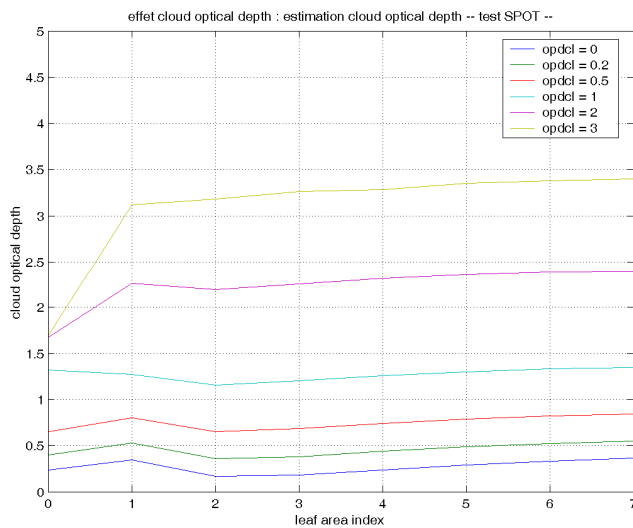
*ratio of NPV from 0 to 1*

**retrieved FBrown (y) versus actual FBrown (x)**



**Figure 10 – Sensitivity to cloud presence (SPOT class)**  
*cloud optical depth from 0 to 3*

**retrieved FCover (y)  
 versus actual FCover (x)**



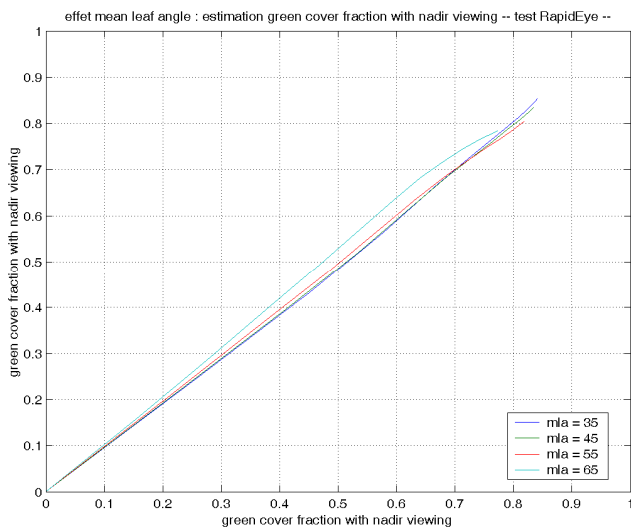
**retrieved cloud optical depth (y)  
 as a function of LAI (x)**

#### 2.4.4 VNIR5 class error estimates

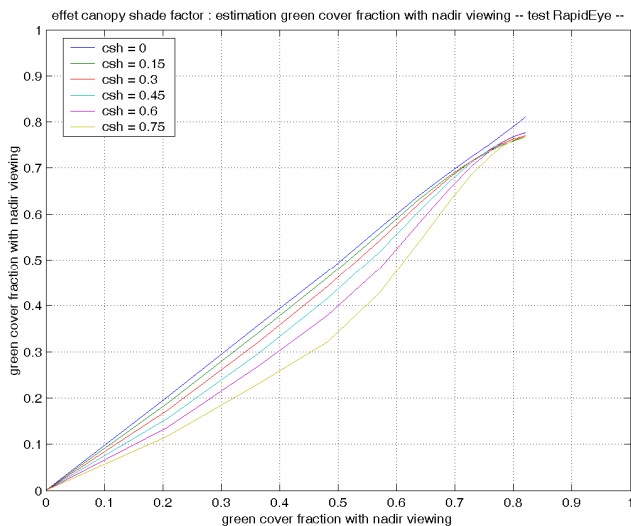
Performances in term of FAPAR, FCover and LAI are fairly similar to the ones obtained for the SPOT class (see figures 11 to 15 **Erreur ! Source du renvoi introuvable.**). Sensitivity to Chlorophyll is better, however due to residual coupling with several other variables (foliage structure and water vapour column in particular), there still remains a significant error level.

As a result, we propose the following range for error estimates (RMS):

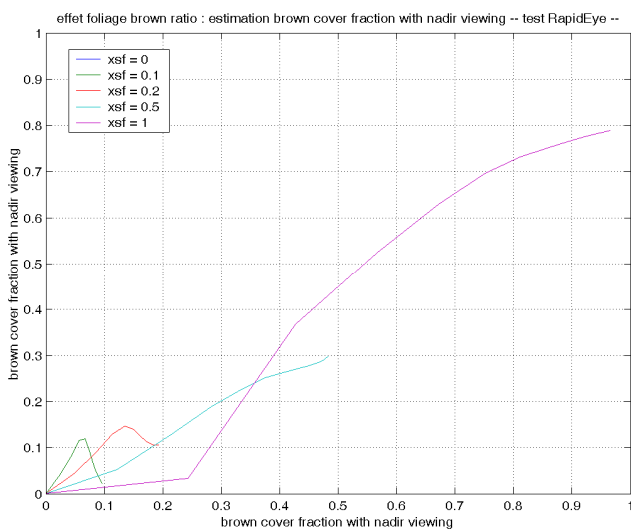
- FCover : 3 – 5 %
- FAPAR : 3 – 5%
- LAI : 20 – 35% (*relative error*)
- Chlorophyll : 5 – 7  $\mu\text{g}/\text{cm}^2$



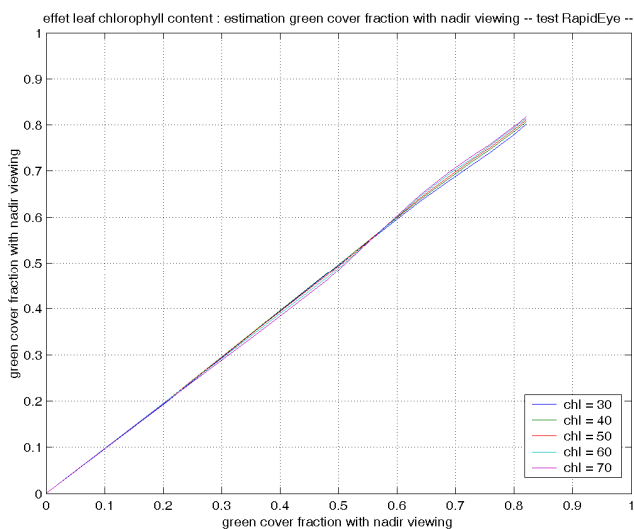
**Figure 11 –  
 Sensitivity to foliage  
 structure  
 (VNIR5 class)  
 retrieved FCover (y)  
 versus actual FCover (x)**



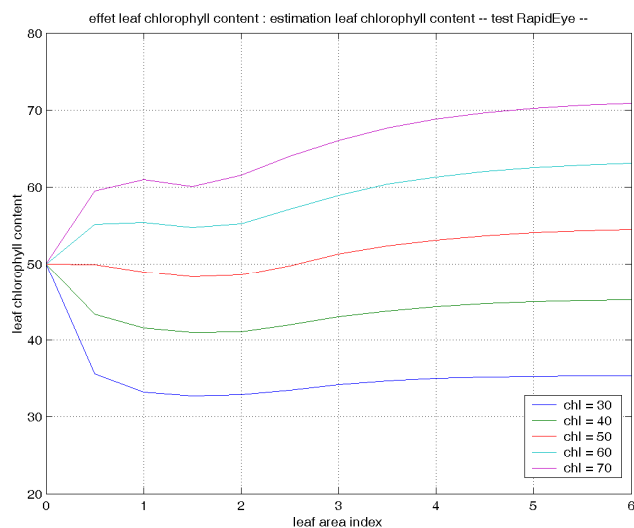
**Figure 12 –  
 Sensitivity to canopy  
 roughness  
 (VNIR5 class)  
 retrieved FCover (y)  
 versus actual FCover (x)**



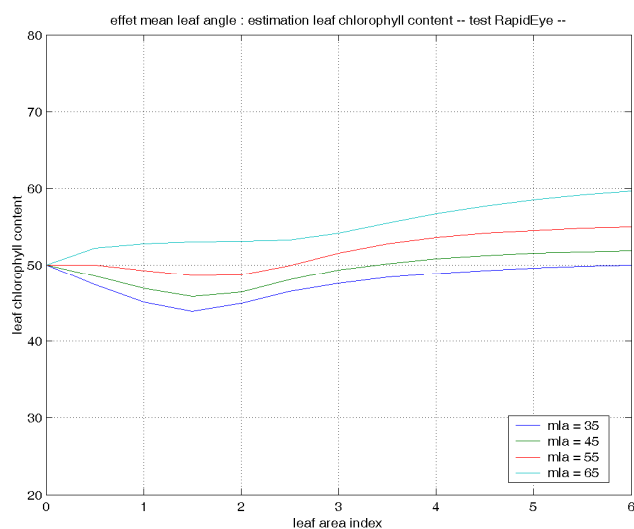
**Figure 13 –  
 Sensitivity to non  
 photosynthetic vegetation  
 (VNIR5 class)  
 retrieved FBrown (y)  
 versus actual FBrown (x)**



**Figure 14 –  
 Sensitivity to chlorophyll  
 (VNIR5 class)  
 retrieved FCover (y)  
 versus actual FCover (x)**



**retrieved Chl (y)  
 as a function of LAI (x)**



**Figure 15 –  
 Sensitivity to foliage  
 structure (VNIR5 class)  
 retrieved Chl (y)  
 as a function of LAI (x)**

## 2.5 LIMITATIONS OF THE PRODUCT

Here is below a discussion of limitations applying to the different products.

### 2.5.1 Fraction of vegetation cover (FCover)

Very dark pixel conditions, due in principle to shadows cast from clouds or topography, are automatically detected and discarded (flagged by the *SHADOW* quality flag). Apart from that case, there is no identified limitation for the FCover product. It is, together with FAPAR, one of the most robust biophysical parameters.

### 2.5.2 Fraction of brown vegetation cover (FBrown)

FBrown quantifies contribution of the non photosynthetic vegetation (NPV). Although not as robust as the same parameter for green vegetation (performance will somehow depend on contrast between local soil and NPV components), there is no identified specific limitation.

### 2.5.3 Leaf Area Index (LAI)

LAI here includes not only green foliage but also the contribution from NPV. It assumes a homogeneous canopy layer. If there is some foliage aggregation at local scale (clumping), the provided LAI is more to be considered as an 'effective' LAI, i.e. the one corresponding to random leaves distribution and producing same remote sensing signal.

### 2.5.4 FAPAR

No limitation for the FAPAR product. Same comments as for Fcover.

### 2.5.5 Fraction of Soil (FSoil)

FSoil is the complement to the vegetation cover fractions. No identified limitation.

### 2.5.6 Chlorophyll (Chl)

Chlorophyll represents the content of chlorophyll per unit surface of leaves. As such, although the Chl information is provided in any pixel classified as Land, it is no meaningful when there is no or little green vegetation. In particular, when there is no green vegetation, the Chl will tend to a default

value<sup>5</sup> of 50  $\mu\text{g}/\text{cm}^2$ . A proposed rule of thumb is to consider Chl values only when LAI > 1 or FCover > 0.3 – 0.4.

In addition, as discussed above, the intrinsic performance of Chl retrieval will be highly dependent on the sensor spectral class. For SPOT-like data, retrieval is rather poor<sup>6</sup> so in the general case it will not be provided.

The PROSPECT model from which Chl is estimated uses a structure parameter N that roughly describes the average number of layers inside the leaf. In fact this parameter may vary according to the plant group and it is quite impossible to retrieve it from remote sensing. As assumption on the N value has a significant impact on Chl estimate, the produced Chl is rather to be considered as an equivalent Chl content for a reference N value (here 1.7).

### 2.5.7 Canopy Shade Factor (CSF)

As for chlorophyll, CSF is a characterisation of the main canopy and so it becomes irrelevant when there is no vegetation, or too little vegetation to properly retrieve its canopy shade conditions. Default CSF value (when there is no vegetation) is 0.

The CSF parameter is not an absolute parameter, as actually depending on image directional conditions. Main variations are observed between HR images of extreme eastward and westwards viewing conditions. Rough canopies like trees and shrubs will however always show significant CSF values, except in some very specific cases (hot-spot conditions). The CSF parameter is also affected by topographic effects.

### 2.5.8 Fraction of Water (FWater)

FWater indicates the fraction of the HR pixel that is covered by water. However, due to strong confusion risks with dark shaded vegetation, the FWater information is only provided for pixels having been classified as Water (or Water / Dark Shadows) in the classification process and showing large FWater values (typically > 70%). When there still remains ambiguity with dark shaded vegetation, this is warned through the *CONFUSION* quality flag.

### 2.5.9 Fraction of Snow (FSnow)

The FSnow parameter indicates the fraction of the HR pixel that is covered by snow, when snow is present. Processing with the *SNOW* theme is only activated on specific regions (e.g. Alpine region, Scandinavia...)

Due to strong confusion risks with clouds, the FSnow information is only provided for pixels having been classified as Snow (or Snow / Clouds) in the classification process and showing significant

---

<sup>5</sup> This is due to the regularisation process of the inversion algorithm.

<sup>6</sup> Still it is able to detect low chlorophyll conditions on closed canopies

FSnow values (typically > 15%). When there still remains ambiguity with clouds<sup>7</sup>, this is warned through the *CONFUSION* quality flag.

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<sup>7</sup> This is true in particular for low altitude clouds, which are difficult to discriminate from cold snow from their spectral characteristics.

### 3 PRODUCT DESCRIPTION

#### 3.1 OVERVIEW

The list of biophysical parameters produced from HR data (BioPar BP-11 products) is recalled here below.

Acronym	Product
FCOVER	Fraction of surface covered by green vegetation
FBROWN	Fraction of surface covered by brown vegetation
FSOIL	Fraction of surface not covered by vegetation (soil)
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
LAI	Leaf Area Index
CSF	Shadow Factor of the vegetation Canopy
FWATER	Fraction of water on the surface
FSNOW	Fraction of snow on the surface

**Table 3 : Summary of BioPar BP-11 products**

It must be noted that the fWater and fSnow products are not automatically produced in the collection depending on the use of specific themes *WATER* and *SNOW*.

BP-11 products are local products generated on user defined areas so called EU-sites for a given date window (typically they may be required for 3-4 periods along the growing season). In the frame of geoland2 activities they are produced on a yearly basis. The table below identifies these test sites.

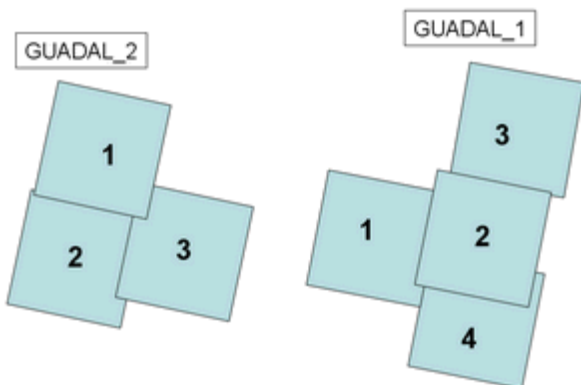
geoland2 site reference	Regions Of Interest	Short Name	User requested projection
EU-08	Rhine river basin	RHINE	LAEA (ETRS89)
EU-09	Seine-Normandie river basin	SEINE	Lambert II étendu (NTF)
EU-10	Guadalquivir river basin	GUADAL	UTM 30N (ED50)
EU-15	Strymonas-Struma river basin	STRUMA	GGRS87 (GRS80)

**Table 4 : Sites covered by the HR production with their short names and attached projection system**

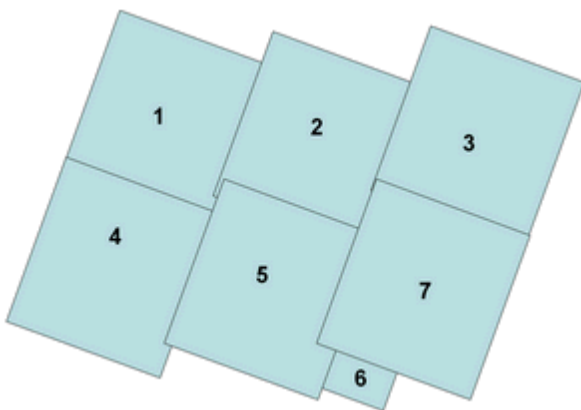
Each site is covered by one or several satellite images. For a better access, some sites have been cut in several sub-sites with an associated code number.

- EU-10: GUADALQUIVIR  
 - GUADAL\_1 (code 1 to 4)

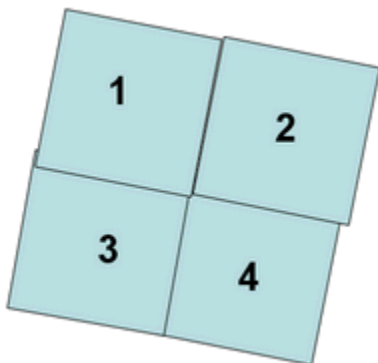
- GUADAL\_2 (code 1 to 3)



- EU-09 : SEINE
  - SEINE (code 1 to 7)
  - SEINE\_RE (RapidEye)



- EU-08: RHINE
  - RHINE (code 1 to 4)
  - RHINE\_RE (RapidEye – code 1 to 8)



## 3.2 FILE FORMAT

The geoland2/BioPar HR products uses the GeoTIFF format for the image products and XML files for the metadata information attached to these products. The metadata is written according to the INSPIRE guidelines

### 3.2.1 File naming

The geoland2/BioPar file name convention is a string of up to 255 characters made of 6 fields separated by single underscores with shape:

**g2 \_ BIOPAR \_ <VariableAcronym> \_ <YYYYMMDDHHMM> \_ <AREA> \_ <SENSOR> \_ V<VersionN>**

where

- *<VariableAcronym>* is the short acronym of each variable (see Table 3)
- *<YYYYMMDDHHMM>* gives the temporal location of the file. *YYYY*, *MM*, *DD*, *HH*, and *MM* denote the year, the month, the day, the hour, and the minutes, respectively. For daily & 10-daily products, 'HHMM' = '0000'.
- *<AREA>* indicates the spatial coverage of the product, here the short name defined for the geoland2 test site.
- *<SENSOR>* gives the short name of the sensor used to retrieve the product. For examples, *S4* corresponds to Spot 4
- *<VersionN>* gives the version number of the product.

### 3.2.2 File structure

The ITF geoland2/BioPar products are delivered as **ZIP archives** containing following files:

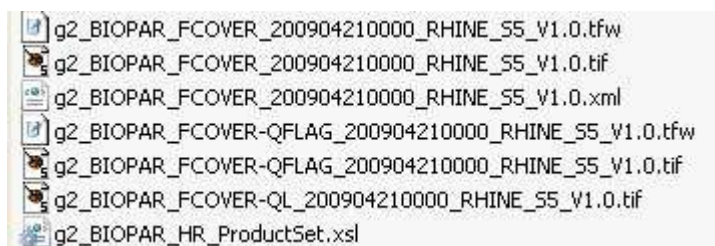
- 1 binary image file for the considered parameter (GeoTIFF)
- 1 binary image file for the quality flags (GeoTIFF)
- 1 RGB image file as quick look image (QL) of the product (GeoTIFF)
- 1 XML metadata file<sup>8</sup> (XML)
- 0 or more metadata translator files (XSLT)
- 1 Copyright Information file (ASCII)

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<sup>8</sup> The XML metadata file is according an internationally standardized format [RD.1].

The products are provided in the form of ZIP archives. The files in the archive are stored in a **subdirectory** that has the decade start date as name, followed by a second **subdirectory** that has the region code plus the real date of the data acquisition as name, e.g. 20090621\GUADAL\_12\_20090625.

Figure 16 shows an example of Geoland2/BioPar files structure.



**Figure 16 – Example of ZIP contents**

### 3.3 PRODUCT CONTENT

#### 3.3.1 Parameter image file

The main image file is a binary image of the considered parameter, in signed integer GeoTIFF format (16 bits).

The scaling factor and offset used for the different parameters are the following<sup>9</sup> :

Acronym	Scaling Factor	Offset	"missing" Value
FCOVER	10000	0	-1
FBROWN	10000	0	-1
FSOIL	10000	0	-1
FAPAR	10000	0	-1
LAI	1000	0	-1
CSF	10000	0	-1
FWATER	10000	0	-1
FSNOW	10000	0	-1

<sup>9</sup> This information will be also provided in the metadata file

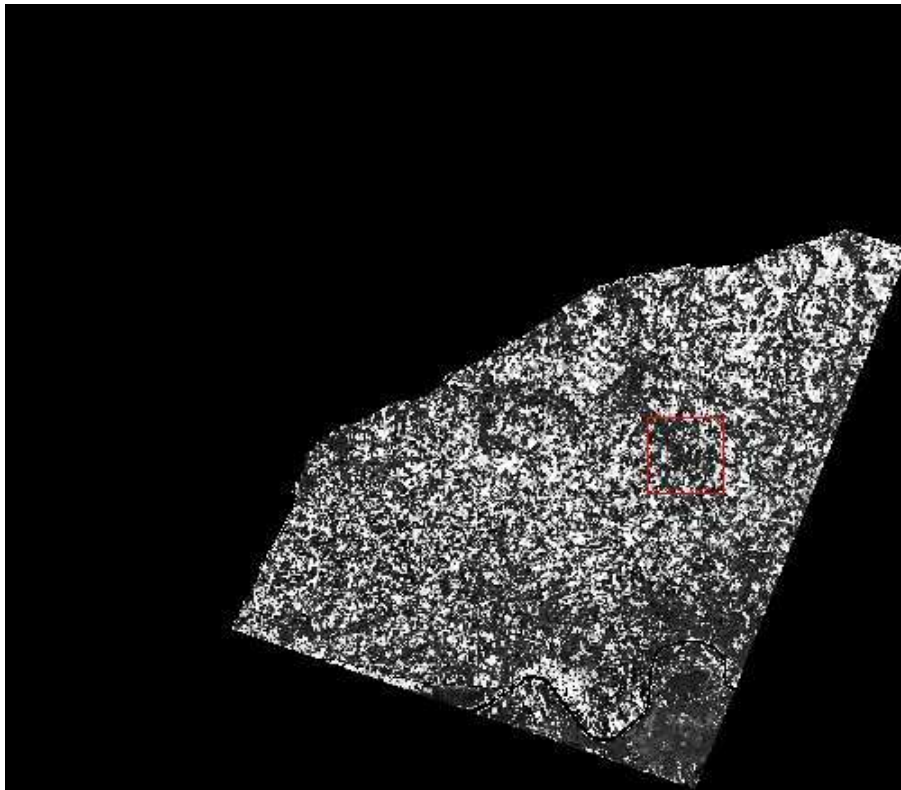


Figure 17 – Example of parameter image (here FSOIL) – North-West coast of France (SEINE)

### 3.3.2 Quality flag image file

The quality flag image file is an additional 8-bits GeoTIFF file with the following flag convention:









Bit	Indication
0	dark shadows
1	clouds
2	water
3	snow
4	confusion
5	bad pixel
6	(reserved)
7	(reserved)

### 3.3.3 Quick look image file

The quick look images (xxx\_QL\_xxx) contain 8-bits per pixel RGB colour table values and are provided in standard TIFF (True Image File Format). Such quick look files provide a first look at the product, and are not to be further processed or analysed. The data in the TIFF quick look images could be 'n' times lower longitudinal and latitudinal resolution than the data in the parameter image file.

Where masked for the considered parameter (clouds, etc), the quick look image is filled in with grey levels of the source image.

The quick look images use a colour chart that is parameter dependent. The table below gives the present colour chart and scaling of each product :

parameter	minimum <i>for colour scale</i>	colour scale	maximum <i>for colour scale</i>
<b>FCover</b>	<b>0</b>		<b>1</b>
<b>FBrown</b>	<b>0</b>		<b>1</b>
<b>LAI</b>	<b>0</b>		<b>6</b>
<b>FAPAR</b>	<b>0</b>		<b>1</b>
<b>FSoil</b>	<b>0</b>		<b>1</b>
<b>CSF</b>	<b>0</b>		<b>1</b>
<b>FWater</b>	<b>0</b>		<b>1</b>
<b>FSnow</b>	<b>0</b>		<b>0.8</b>

**Table 5 : Colour charts used for HR products QuickLooks**

An example of product quick look is provided in Figure 18.

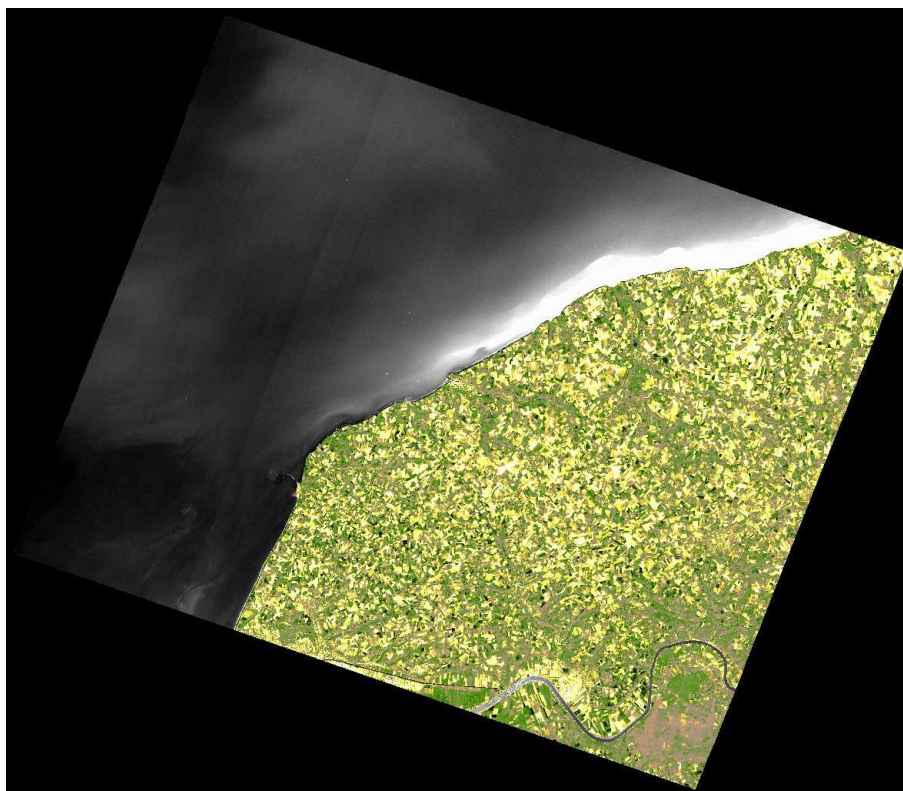


Figure 18 – Example of quick look image (here FSOIL) – North-West coast of France (SEINE)

### 3.3.4 Metadata file

All metadata information is presented in an XML file that can be easily viewed in a regular web browser using the XSL translator file (g2\_BIOPAR\_PROD-DESC.xsl). The viewer can easily be replaced by an own viewer by substituting the corresponding xsl tag in the xml file viewer with the name of another XSL translator file.

The product descriptions follow the international standards ISO 19115 (version 2003) and ISO 19139 (version 2005), that are defined by the International Standards Organization (ISO) and supported by the OpenGIS Consortium (OGC).

More precisely, ISO 19139 provides a set of XSD (XML Schema Definition) files, that were derived from the metadata structure designed in ISO 19115 and that contain the rules that the XML format must obey.

As defined in the ISO standards, a MD\_MetaData element must be at the top level in the XML hierarchy and only 1 top-level element is allowed.

The common attributes as presented in the XML file are described below.

Attributes indicated with the S type are static, i.e. they are fixed for a given product. Other information fields are dynamic, i.e. set individually for each product.

Attribute	Description / comments	Type
<i>Product and Production Information</i>		
Name	Title with elements to discriminate the different products (example: tile or date or both) generated automatically during production	S
Identifier	Product Identifier (ID)	D
Version	Version of product	D
Abstract	Product short product description	S
Algorithm	Algorithm description (reference to PUM)	S
Purpose	Typical applications (reference to PUM)	S
Platform	Sensor source used for this product	S
Sensor	Sensor source used for this product	S
Keywords	Keywords attached	S
Topic Categories	Application topics	S
Production Centre	Name of production centre	D
Production Date	Date/time of generation of the product	D
Product Status	Status of the collection / product	D
<i>Spatial Information</i>		
Projection	Projection name	D
Projection Code	EPSG code of projection	D
Ellipsoid	Ellipsoid name	D
Resolution	Spatial resolution	D
Unit	Spatial unit (e.g. Meters or Degrees)	D
Region Code	ID of processed Region of Interest / Tile	D
Region Name	Full name of processed Region of Interest / Tile	D
Northern Boundary	Latitude max (decimal degrees)	D
Southern Boundary	Latitude min (decimal degrees)	D
Western Boundary	Longitude min (decimal degrees)	D
Eastern Boundary	Longitude max (decimal degrees)	D
Number of Lines	Image size: number of lines (records)	D
Number of Columns	Image size: number of columns (samples)	D
Reference Point	Corner used as reference	D
Raster Reference	Raster type convention (center or upper left of pixel)	D
<i>Temporal Information</i>		
Description	Description of applied temporal processing	S
Start Date	Start date of product period	D
End Date	End date of product period	D
Effective Date	Effective date of the product, i.e. actual date if single acquisition or reference date if time filtered/interpolated product	D
<i>Product Value Information</i>		
Max Physical Value	Max physical value of parameter	S

Attribute	Description / comments	Type
Min Physical Value	Min physical value of parameter	S
Value Type	Type used for image value coding	S
Scale Factor	Scaling factor applied for image value coding	S
Offset	Offset applied for image value coding	S
Invalid Value	Code convention for missing values	S
<i>Distribution Information</i>		
Product Format	Description of image product format	S
Product Size	Actual size of the zip file, required for distribution	D
Distribution Format	Description of distribution format (e.g. zip)	S
<i>Data URL</i>		
URL QuickLook	Reference to any files that contain a thumbnail of or first quick look at the dataset	D
URL Product	On-line access to the product (URL)	D
<i>Data Policies</i>		
Credit	Credit to geoland2	S
Copyright	Copyright	S
Use Limitations	Limitations of product usage	S
<i>Contact</i>		
Scientific contact		S
Scientific e-mail		S
Production contact		S
Production e-mail		S
Distributor contact		S
Distributor e-mail		S
<i>Data Quality Information</i>		
Validation Results	Reference to achieved validation results (report, etc.)	S

**Table 6 : Description of information provided in the XML attributes**

The following table indicates location of these attributes in the XML file

Attribute	XML Element
<i>Product and Production Information</i>	
Name Identifier	MD_Metadata\identificationInfo\MD_DataIdentification\citation\CI_Citation\title
Version	MD_Metadata\identificationInfo\MD_DataIdentification\citation\CI_Citation\edition
Abstract	MD_Metadata\identificationInfo\MD_DataIdentification\abstract

Attribute	XML Element
Algorithm	MD_Metadata\dataQuality\Info\DQ_DataQuality\lineage\LI_Lineage\statement
Purpose	MD_Metadata\identificationInfo\MD_DataIdentification\purpose
Platform	MD_Metadata\identificationInfo\MD_DataIdentification\aggregationInfo[.]\initiativeType\DS_InitiativeTypeCode
Sensor	MD_Metadata\identificationInfo\MD_DataIdentification\aggregationInfo[.]\initiativeType\DS_InitiativeTypeCode
Keywords	MD_Metadata\identificationInfo\MD_DataIdentification\descriptiveKeywords[.]\MD_Keywords\keyword
Topic Categories	MD_Metadata\identificationInfo\MD_DataIdentification\topicCategory[.]
Production Centre	MD_Metadata\identificationInfo\MD_DataIdentification\citation\CI_Citation\identifier\MD_Identifier\authority\CI_Citation\title
Production Date	Gmd:identificationInfo:citation:editionDate
Product Status	MD_Metadata\identificationInfo\MD_DataIdentification\status\MD_ProgressCode
<b>Spatial Information</b>	
Projection	MD_Metadata\referenceSystemInfo\MD_CRS\projection\codeSpace
Projection Code	???
Ellipsoid	MD_Metadata\referenceSystemInfo\MD_CRS\ellipsoid\codeSpace
Resolution	MD_Metadata\identificationInfo\MD_DataIdentification\spatialResolution\MD_Resolution\distance
Unit	MD_Metadata\identificationInfo\MD_DataIdentification\spatialResolution\MD_Resolution\distance[attribute]
Region Code	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\geographicElement\EX_GeographicBoundingBox\shortid
Region Name	Gmd:identificationInfo:descriptiveKeywords "place"
Northern Boundary	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\geographicElement\EX_GeographicBoundingBox\northBoundLatitude
Southern Boundary	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\geographicElement\EX_GeographicBoundingBox\southBoundLatitude
Western Boundary	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\geographicElement\EX_GeographicBoundingBox\westBoundLatitude
Eastern Boundary	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\geographicElement\EX_GeographicBoundingBox\eastBoundLatitude
Number of Lines	MD_Metadata\spatialRepresentationInfo\MD_Georectified\axisDimensionProperties[.]\MD_Dimension\dimensionSize
Number of Columns	MD_Metadata\spatialRepresentationInfo\MD_Georectified\axisDimensionProperties[.]\MD_Dimension\dimensionSize
Reference Point	MD_Metadata\spatialRepresentationInfo\MD_Georectified\checkPointDescription
Raster Reference	MD_Metadata\spatialRepresentationInfo\MD_Georectified\pointInPixel\MD_PixelOrientationCode
<b>Temporal Information</b>	
Description	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\temporalElement\EX_TemporalExtent\extent\gml:TimePeriod\gml:description
Start Date	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\temporalElement\EX_TemporalExtent\extent\gml:TimePeriod\gml:beginPosition
End Date	MD_Metadata\identificationInfo\MD_DataIdentification\extent[.]\EX_Extent\temporalElement\EX_TemporalExtent\extent\gml:TimePeriod\gml:endPosition
Effective Date	0
<b>Product Value Information</b>	
Max Physical Value	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*
Min Physical Value	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*
Value Type	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*
Scale Factor	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*

Attribute	XML Element
Offset	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*
Invalid Value	MD_Metadata\contentInfo\MD_CoverageDescription\dimension\MD_Band*
<b>Distribution Information</b>	
Product Format	MD_Metadata\identificationInfo\MD_DataIdentification\resourceFormat\MD_Format\name+version
Product Size	Gmd:distributionInfo:
Distribution Format	MD_Metadata\distributionInfo\MD_Distribution\distributionFormat\MD_Format\name+version
<b>Data URL</b>	
URL QuickLook	MD_Metadata\identificationInfo\MD_DataIdentification\graphicOverview\MD_BrowseGraphic\fileName
URL Product	0
<b>Data Policies</b>	
Credit	MD_Metadata\identificationInfo\MD_DataIdentification\credit
Copyright	MD_Metadata\identificationInfo\MD_DataIdentification\resourceConstraints\MD_LegalConstraints\useConstraints\MD_RestrictionCode
Use Limitations	MD_Metadata\identificationInfo\MD_DataIdentification\resourceConstraints\MD_LegalConstraints\useLimitation
<b>Contact</b>	
Scientific contact	MD_Metadata\identificationInfo\MD_DataIdentification\pointOfContact\CI_ResponsibleParty\organisationName
Scientific e-mail	MD_Metadata\identificationInfo\MD_DataIdentification\pointOfContact\CI_ResponsibleParty\contactInfo\CI_Contact\electronicMailAddress
Production contact	MD_Metadata\identificationInfo\MD_DataIdentification\pointOfContact\CI_ResponsibleParty\organisationName
Production e-mail	MD_Metadata\identificationInfo\MD_DataIdentification\pointOfContact\CI_ResponsibleParty\contactInfo\CI_Contact\electronicMailAddress
Distributor contact	MD_Metadata\distributionInfo\MD_Distribution\distributor\distributorContact\CI_ResponsibleParty\organisationName
Distributor e-mail	MD_Metadata\distributionInfo\MD_Distribution\distributor\distributorContact\CI_ResponsibleParty\contactInfo\CI_Contact\electronicMailAddress
<b>Data Quality Information</b>	
Validation Results	MD_Metadata\dataqualityInfo\DQ_DataQuality\report\explanation

**Table 7 : Location of XML attributes according to ISO19115**

### 3.4 SUMMARY OF PRODUCT CHARACTERISTICS

#### **Physical definition, unit and range**

Acronym	Product	Unit	Range
FCOVER	Fraction of surface covered by green vegetation	—	0 – 1
FBROWN	Fraction of surface covered by brown vegetation	—	0 – 1
FSOIL	Fraction of surface not covered by vegetation (soil)	—	0 – 1
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation	—	0 – 1
LAI	Leaf Area Index	m <sup>2</sup> / m <sup>2</sup>	0 – 10
CSF	Shadow Factor of the vegetation Canopy	—	0 – 1
FWATER	Fraction of water on the surface	—	0 – 1
FSNOW	Fraction of snow on the surface	—	0 – 1

#### **Input satellite data**

Products are derived from various HR sensors

#### **Geographical definition**

Products are produced in site-specific projection coordinate system (Table 4), with the spatial resolution of the source data.

#### **Coverage**

Local products over user-defined areas.

#### **Output product**

Output format is GeoTIFF signed integer (16 bits) for the parameter map, GeoTIFF 8 bits for quality flag and GeoTIFF 8bits colour table for QuickLook. Metadata information is provided in attached XML file.

#### **Temporal definition**

Generated typically at 3-4 dates along the season, in defined period windows (depending on user request). For the year 2009, the target acquisition periods are 20/03→30/05, 01/06→30/06 and 01/09→30/09.

#### **Delivery time**

Once a year

#### **Data Policies**

The user understands that the distribution of the above-mentioned product implies the obligation for him to include in any publication or communication using these products the following citation:

***“The research leading to these results has received funding from the European Community’s Seventh Framework Program (FP7/2007-2013) under grant agreement n°218795. These products are the property of Infoterra France under copyright geoland2. They have been generated from satellite HR data provided by the European Space Agency.”***

Products generated within the frame of the geoland2 project are free of use for non-commercial applications. Contact Infoterra France for any commercial use of the product.

The user accepts to inform geoland2/BioPar about the outcome of the use of the above-mentioned product and to send a copy of any publications that use this product to the following address [helpdesk@geoland2.eu](mailto:helpdesk@geoland2.eu).

### **Contacts**

For any questions about the methodology of generation of HR products, please contact [Herve.Poilve@infoterra.fr](mailto:Herve.Poilve@infoterra.fr).

For any questions the production and the dissemination of HR products, please contact [geoland2@infoterra.fr](mailto:geoland2@infoterra.fr).

## **4 VALIDATION**

### **4.1 OVERVIEW**

This chapter summarises the results obtained to validate the presented product, and the identified limitations.

### **4.2 VALIDATION PROCEDURE**

Validation of the HR products is part of the scientific validation work performed within the frame of geoland2 project (leading partner EOLAB). Validation is performed on 6 selected sites of the former VALERI project, corresponding to various cover types (crops, grassland, forest and other natural vegetation).

Comparison made with reference ground measurements (using CAN-EYE or LAI-2000) performed on sampling sites (ESU = Elementary Sampling Units) and with the LAI, FAPAR and fCover maps derived from these ground measurements using the VALERI approach (use of transfer functions to extrapolate sampling points results to the whole image area).

### **4.3 RESULTS**

Please refer to the Validation Report of High Resolution Vegetation Parameters (geoland2 BP-RP-BP022) for a detailed discussion of the results.

### **4.4 LIMITATIONS OF THE PRODUCT**

## 5 REFERENCES

- [1] EADS Astrium and project partners (2002), **CROMA (Crop Reflectance Operational Models for Agriculture) Final Report** – EU shared cost research project – Contract EVG1-CT-2000-00027.
- [2] Infoterra Ltd, EADS Astrium and project partners (2004), **ISOCrop (Integrating SAR with Optical products for Crop Management) Final Report** – EU shared cost research project – Contract EVG1-CT-2001-00053.
- [3] Jacquemoud, S. and Baret, F.(1990). **PROSPECT: A model of leaf optical properties spectra**, Remote Sensing of Environment 34: 75-91.
- [4] Jacquemoud S., Bacour, C., Poilvé H., Frangi JP., (2000). **Comparison of Four Radiative Transfer Models to Simulate Plant Canopies Reflectance – Direct and Inverse Mode**. Remote Sensing of Environment, 74(3):471-481.
- [5] Jacquemoud, S., Verhoef, W., Baret, W., Bacour, C., Zarco-Tejada, P.J., Asner, G.P., François, C., Ustin, S.L., (2009) **PROSPECT+SAIL: 15 Years of Use for Vegetation Characterization**. Remote Sensing of Environment, 113, pS56-S66.
- [6] Kneisys F.X. et al, (1988), **Users Guide to LOWTRAN 7**, Air Force Geophysics Lab Hanscom AFB MA
- [7] Kötz, B., F. Baret, H. Poilvé and J. Hill (2005). **Use of coupled canopy structure dynamic and radiative transfer models to estimate biophysical canopy characteristics**. Remote Sensing of Environment, 95: 115-124
- [8] Matra Marconi Space and project partners (1999), **PAAGE (Pilot project for Agriculture and Agri Environment) Final Report** – EU shared cost research project – Contract ENV4-CT97-0400.
- [9] Kneisys F.X., Abreu L.W., Anderson G.P., Chetwynd J.H, et al., (1995): **The MODTRAN 2/3 and LOWTRAN 7 Model**. Philips Laboratory, prepared by Ontar Corporation, North Andover (MA), 267 pp.
- [10] Verhoef, W. (1984). **Light scattering by leaf layers with application to canopy reflectance modeling: the SAIL model**, Remote Sensing of Environment 16: 125-141.
- [11] Verhoef, W. (1985). **Earth observation modeling based on layer scattering matrices**, Remote Sensing of Environment 17: 165-178.
- [12] Verhoef, W. and Bach, H. (2003), **Simulation of hyperspectral and directional radiance images using coupled biophysical and atmospheric radiative transfer models**, Remote Sensing of Environment 87 23–41