Standards for in situ LAI and biophysical variables measurements

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16-17 November, 2015
Context - Validation needs

• Copernicus Global Land products (as well as any other EO product) must be validated. According to CEOS LPV best practices:
  ➢ Product accuracy should be assessed through a significant set of locations and time periods
  ➢ None of the existing networks are oriented to global LAI/FAPAR product validation

• **Need for ground LAI/FAPAR data processed according to CEOS LPV** for validation of satellite products from the current and coming missions
Introduction

• ImagineS is supporting the evolution of Copernicus Global Land Service, by developing processing lines for PROBA-V 333 m products, and supporting ground based data collection for validation.

• In-situ standards based on EO product validation needs (spatial representativeness and up-scaling), in agreement with CEOS LPV guidelines for LAI validation:
  - Heritage from VALERI initiative (lead by INRA)
  - Adopted in many ESA cal/val campaigns

• Guidelines for in-situ LAI, FAPAR, Fcover measurements were provided to ‘teams’ over 17 sites (including some of JECAM sites)
ImagineS ground based LAI /FAPAR collections

data available at fp7-imagines.eu

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CAMPAIGNS</th>
<th>ESUS</th>
<th>MEASUREMENTS</th>
<th>LAleaf</th>
<th>LAI</th>
<th>FAPAR</th>
<th>FCover</th>
<th>TOTAL</th>
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</table>

25-Mayo, La Pampa

JECAM
Joint Experiment for Crop Assessment and Monitoring

GROUP ON EARTH OBSERVATIONS
Definition

LAI is defined as one half the total leaf area per unit horizontal ground surface area (Chen and Black, 1992; GCOS, 2010). It is dimensionless \((m^2.m^{-2})\). However, this simple definition needs some additional comments when applied to remote sensing observations.

<table>
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<tr>
<th>Type of element</th>
<th>Element color</th>
<th>Methodology</th>
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<tbody>
<tr>
<td>Leaves or needles</td>
<td>Green</td>
<td>GLAI, Destructive meas.</td>
</tr>
<tr>
<td></td>
<td>Green and non-green</td>
<td>LAI, Destructive meas.; litter fall baskets</td>
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<tr>
<td>All elements</td>
<td>Green</td>
<td>GAI, Destructive meas., Remote sensing estimates, indirect methods from top of canopy</td>
</tr>
<tr>
<td></td>
<td>Indirect methods from bottom of canopy; LIDAR</td>
<td>PAI</td>
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</table>

JECAM
Joint Experiment for Crop Assessment and Monitoring

GEO
GROUP ON EARTH OBSERVATIONS
Definition

• **Understory/overstory**
  Since remote sensing observations will be mostly sensitive to the cumulated value of green area, both the green overstory and understory should be accounted for when computing leaf area index. The understory may represent a very significant fraction of canopy leaf area index.

• **Effective/actual LAI**
  Most LAI (GAI) ground measurements used for the validation is based on indirect measurements assuming random distribution of the elements within the canopy volume (i.e. no clumping), which corresponds to an effective LAI (GAI). To obtain the actual LAI value, the clumping should be accounted for.

Devices such as digital hemispherical photographs or TRAC instrument allows to estimate clumping index.
Rice, Honghe Farm, China

H. Fang et al. / Agricultural and Forest Meteorology 198–199 (2014) 126–141
Devices

1) Gap fraction ($P_0$)

- **Fish-Eye digital photos (DHP)**

  Join Retrieval of LAI, FAPAR and FCOVER

  \[ P_0(\theta_v, \varphi_v) = e^{-N \cdot (\theta_v \cdot \varphi_v)} = e^{-G \cdot (\theta_v \cdot \varphi_v) \cdot \cos(\theta_v)} \]

  \[ FAPAR^{BS}(\theta_S) = 1 - P_0 \cdot (\theta_S) \]

  \[ FC\text{OVER} = 1 - P_0 \cdot (0 - 10^\circ) \]

- **LICOR LAI 2200** (Miller’s method)

\[ P\text{AI}_{eff} = 2 \int_0^{\pi/2} - \ln P_0(\theta) \cos \theta \sin \theta d\theta \]

2) PAR transmission (centimeters)

- **AccuPar** (Norman and Welles, 1983)

  \[ P\text{AI}_{eff} = \frac{[(1 - (1/2k)f_b - 1)\ln \tau}{A(1 - 0.47f_b)} \]

  FAPAR ≈ 1 - Transmittance

- **Others**: SunScan, Solems PAR

- **Others**: TRAC
Protocol - Individual LAI sampling
(ESU - Elementary Sampling Unit)

- It is recommended to use indirect methods (DHP is preferred) and to define properly the variable measured related to LAI, i.e., document well the way the LAI is derived for an appropriate LAI definition:

- **The presence of non-green elements** and the way it was accounted for or not

- **The type of LAI computation achieved**: Effective or Actual LAI. In the latter case, the way leaf clumping is accounted for should be documented.

- **The presence of understory**

- **The illumination conditions** used when making the measurements

**Sampling scheme**

Random - homogeneous

Row crops

Regular Plantation
Protocol - Sampling the Site

- **Size of the site:**
  - 3-km x 3-km

- **Number of ESUs:**
  - 30 - 50 sampling units

- **Size of the ESU:**
  - ~ 20 m x 20 m (GPS at centre)

- **Sampling the site:**
  - Stratified, based on land cover
  - 3-5 ESUs per field to cover intra-field variability
  - Additional control points (bare /senescent)
  - Avoid borders (Adjacency effects)

- **Sampling the ESU:**
  - 13 shots (DHP)
  - 27 (3 up x 9 down) replications (LAI-2200, ceptometers)
Protocol - Reporting

- Comprehensive Database
  - Header information
  - Ground dataset
  - Summary table

- For each ESU
  - The position (coordinates)
  - The dimension (typical diameter)
  - The altitude
  - The date of measurement
  - The type of vegetation and state
  - The measurement performed (Method, sampling, processing, value and uncertainties).

<table>
<thead>
<tr>
<th>Column</th>
<th>Var Name</th>
<th>Comment</th>
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<tr>
<td>1</td>
<td>Plot #</td>
<td>Number of the field plot</td>
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<td>Plot Label</td>
<td>Label of the plot</td>
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<tr>
<td>3</td>
<td>ESU #</td>
<td>Number of the Elementary Sampling Unit (ESU)</td>
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<td>4</td>
<td>ESU Label</td>
<td>Label of the ESU in the campaign</td>
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<tr>
<td>5</td>
<td>Northing Coord.</td>
<td>Geographical coordinate: Latitude (º), WGS-84</td>
</tr>
<tr>
<td>6</td>
<td>Easting Coord.</td>
<td>Geographical coordinate: Longitude (º), WGS-84</td>
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<td>7</td>
<td>Extent (m) of ESU (diameter)</td>
<td>Size of the ESU</td>
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<td>Land Cover</td>
<td>Detailed land cover</td>
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<td>Start Date (dd/mm/yyyy)</td>
<td>Starting date of measurements</td>
</tr>
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<td>10</td>
<td>End Date (dd/mm/yyyy)</td>
<td>Ending date of measurements</td>
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<td>Method Instrument</td>
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<td>Nb. Replications</td>
<td>Number of Replications</td>
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<tr>
<td>13</td>
<td>LAIeff</td>
<td>Computed from the gap fraction as a function of the angle</td>
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<td>Uncertainty LAIeff standard deviation</td>
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<td>15</td>
<td>LAI</td>
<td>LAItrue = LAIeff/clumping index</td>
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<td>Uncertainty LAItrue standard deviation</td>
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<td>18</td>
<td>Nb. Replications</td>
<td>Number of Replications</td>
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<tr>
<td>19</td>
<td>FAPAR</td>
<td>Measured daily integrated FAPAR under direct illumination conditions at a given solar position</td>
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<td>Uncertainty FAPAR standard deviation</td>
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<td>FCOVER</td>
<td>Retrieved from gap fraction, fCover = 1-Po(0-10º)</td>
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<td>Number of Replications</td>
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<tr>
<td>27</td>
<td>Leaf WC (g/m2)</td>
<td>Leaf WC = (FWT-DWT)/Aleaf</td>
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<td>Uncertainty Leaf WC uncertainty</td>
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<tr>
<td>29</td>
<td>Canopy WC (kg/m2)</td>
<td>Canopy WC = leaf WC * LAI</td>
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<td>Uncertainty Canopy WC uncertainty</td>
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<td>31</td>
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<td>Leaf Ch (microg/cm2)</td>
<td>Leaf Chlorophyll Content</td>
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<td>Canopy Ch (mg/m2)</td>
<td>Canopy Chlorophyll Content = leaf Ch * LAI</td>
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<td>37</td>
<td>LAI57eff</td>
<td>Effective leaf area index calculated at the 57.5 zenith angle</td>
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<tr>
<td>38</td>
<td>FAPAR (white sky)</td>
<td>white sky (or diffuse) FAPAR</td>
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<tr>
<td>39</td>
<td>FWT (g)</td>
<td>Sample fresh weight. Sample includes aprox. 95% of leaves and 5% of stems</td>
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<tr>
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<td>DWT (g)</td>
<td>Sample dry weight</td>
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<td>Aleaf (m2)</td>
<td>Sample area</td>
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<tr>
<td>42</td>
<td>Unclassified pixels (%)</td>
<td>Unclassified pixels in the estimation of sample area</td>
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</tbody>
</table>

COMMENTS
Additional comments.
DHP acquisitions

- Downward looking photos:
  
  Low vegetation canopies

  Very dense canopies, as the camera will modify the structure of the canopy.

  Alfalfa - downward  Upward  Pappaver- down  upward
Processing DHP with CAN-EYE

www4.paca.inra.fr/can-eye
Three methods are used CEv5.1, CEv6.1, Miller’s (LAI-2000)

For LAIeff, it is recommended to average the three and report the STD as uncertainty
For LAI, it is recommended to average only CEv6.1, CEv5.1 (large differences for the other method)
DHP calibration (CAN-EYE)

Optical centre and Projection Function

Optical centre

Projection Function

Small FOV

Alignment

Example for EOLAB system and camera from TULA site
**Special cases**

- **Heterogeneous ESUs**

The retrieved values in heterogeneous ESUs will be dependent of the picture selected for the classification process.

In very heterogeneous situations, it is recommended to **process twice** the ESU selecting two different pictures for classification, and provide averaged values and uncertainties.
Special cases

- ESUs showing non-stable retrievals

To process the ESUs twice (one classifying vegetation and other classifying sky/soil, and provide the average
Special cases

- **Representativeness of the image**

Select an image representative of the sampling, this improve and makes stable the retrieval.

Remove pictures saturated

Remove the saturated picture
Special cases

- Clumping is an important uncertainty factor regarding LAI estimate. For very homogeneous and dense crop canopies, the clumping should be close to 1. The DHP provides unreliable values in this type of crops which can increase the actual LAI up to 7-8.
- It is recommended to set up to 0.95 manually (just for very dense and homogeneous canopies)

![Alfalfa (Clumping 0.77)](image1)

![Papaver Somniferum (Clumping 0.68)](image2)
Special cases

- Plots with understory/overstory

- \( LAI = LAI_{ABOVE} + LAI_{BELOW} \)
- \( FCOVER = 1 - (1 - FCOVER_{ABOVE}) \cdot (1 - FCOVER_{BELOW}) \)
- \( FAPAR = 1 - (1 - FAPAR_{ABOVE}) \cdot (1 - FAPAR_{BELOW}) \)
Standard procedure for in-situ LAI collection has been established in the context of validation of LAI remote sensing products (CEOS LPV best practices). Indirect methods are recommended.

Document well the way the LAI is derived, and the presence of non-green elements (understory, etc).

Clumping index should be estimated for an actual LAI estimation.

DHP is recommended as they allow the estimation of Green Area Index, close to green LAI. And join retrieval of FAPAR, FCOVER. The photo provides further visual information for interpretation. LICOR-2200 and TRAC instruments are also good solutions for LAI.

Sample the spatial heterogeneity at ESU level (15), field level (3-5), and site level 30-50 ESUs), and additional control points (bare /senescent).

DHP processing shall be performed by trained people, otherwise could lead to important errors (up to 1 in LAI), or even greater in particular cases. For difficult cases, process twice the ESU (sky/soil or choosing different pictures) and provide average values.

By adopting some of these recommendations, JECAM could support the long-term provision of LAI measurements for the validation of satellite biophysical product (Copernicus and other missions), contributing to CEOS LPV reference dataset.

Ongoing collaboration with few JECAM sites.
Thank you for your attention

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