Standards for in situ LAI and biophysical variables measurements

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JECAM
Joint Experiment for Crop Assessment and Monitoring

GEO GROUP ON EARTH OBSERVATIONS

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 trough 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

Stage 1 Validation	Product accuracy is assessed from a small (typically < 30) set of locations and time periods by comparison with in-situ or other suitable reference data.
Stage 2 Validation	Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.
Stage 3 Validation	Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically robust way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.
Stage 4 Validation	Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands.

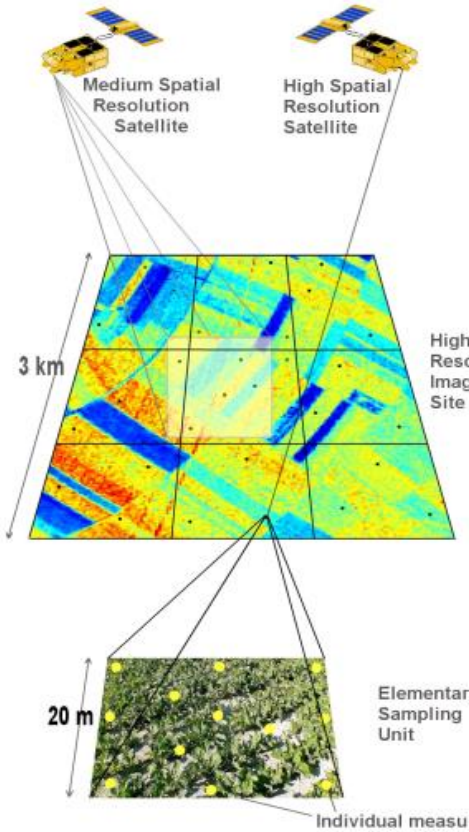
Introduction

• 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)



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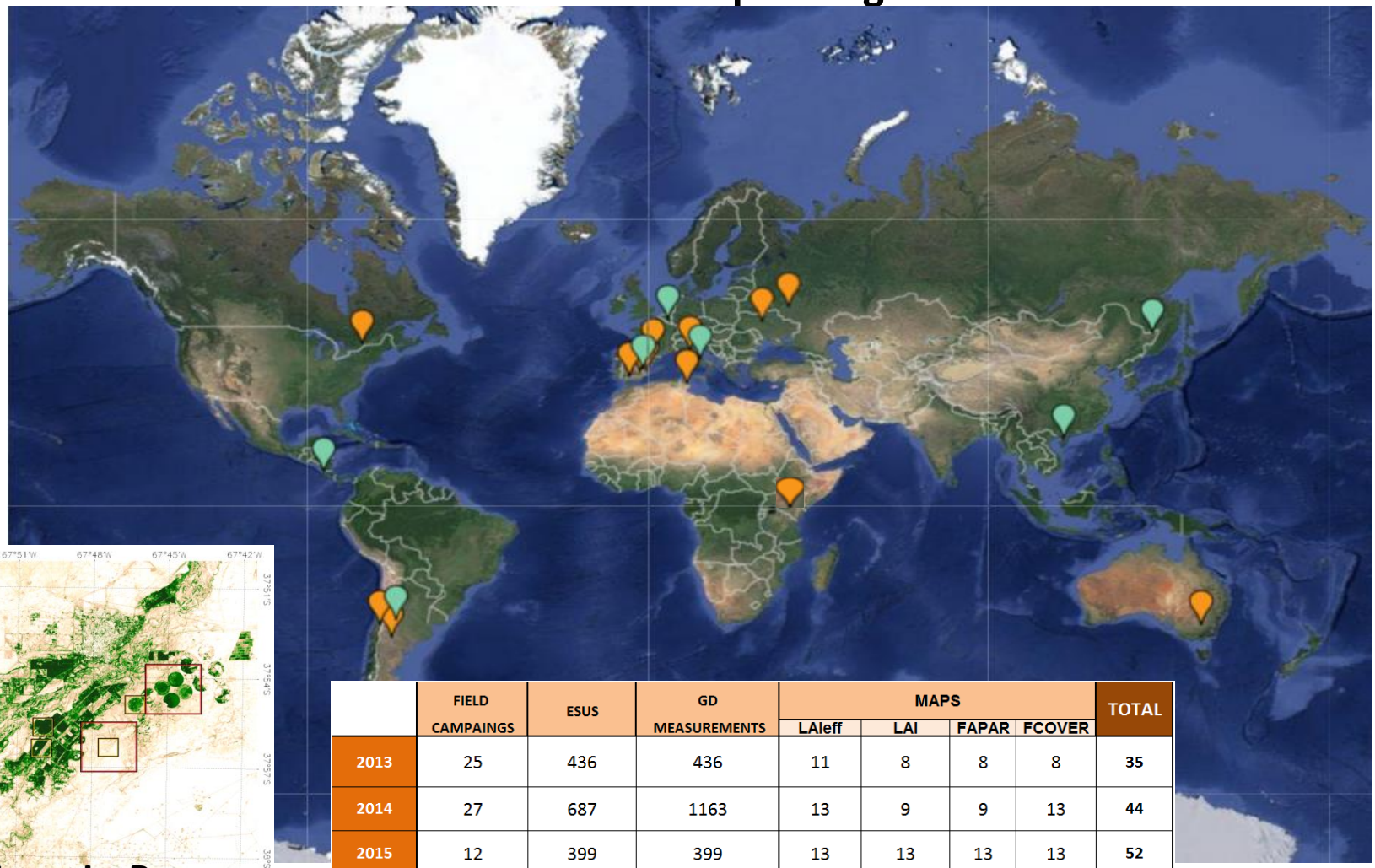
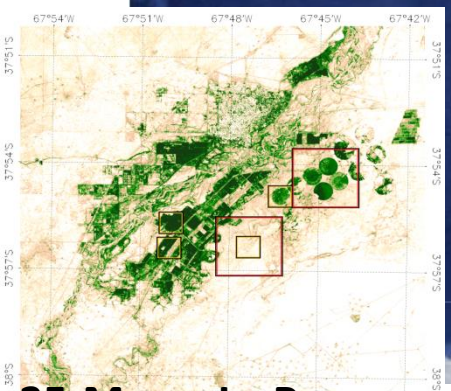
ImagineS ground based LAI /FAPAR collections

data available at fp7-imagines.eu





25-Mayo, La Pampa

	FIELD CAMPAINGS	ESUS	GD MEASUREMENTS	MAPS				TOTAL
				LAIeff	LAI	FAPAR	FCOVER	
2013	25	436	436	11	8	8	8	35
2014	27	687	1163	13	9	9	13	44
2015	12	399	399	13	13	13	13	52
2013-2015	64	1522	1998	37	30	30	34	131

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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

		Element color	
		Green	Green and non-green
Type of element	Leaves or needles	**GLAI** *Destructive meas.*	**LAI** *Destructive meas.; litter fall baskets*
	All elements	**GAI** *Destructive meas., Remote sensing estimates, indirect methods from top of canopy*	**PAI** *Indirect methods from bottom of canopy; LIDAR*

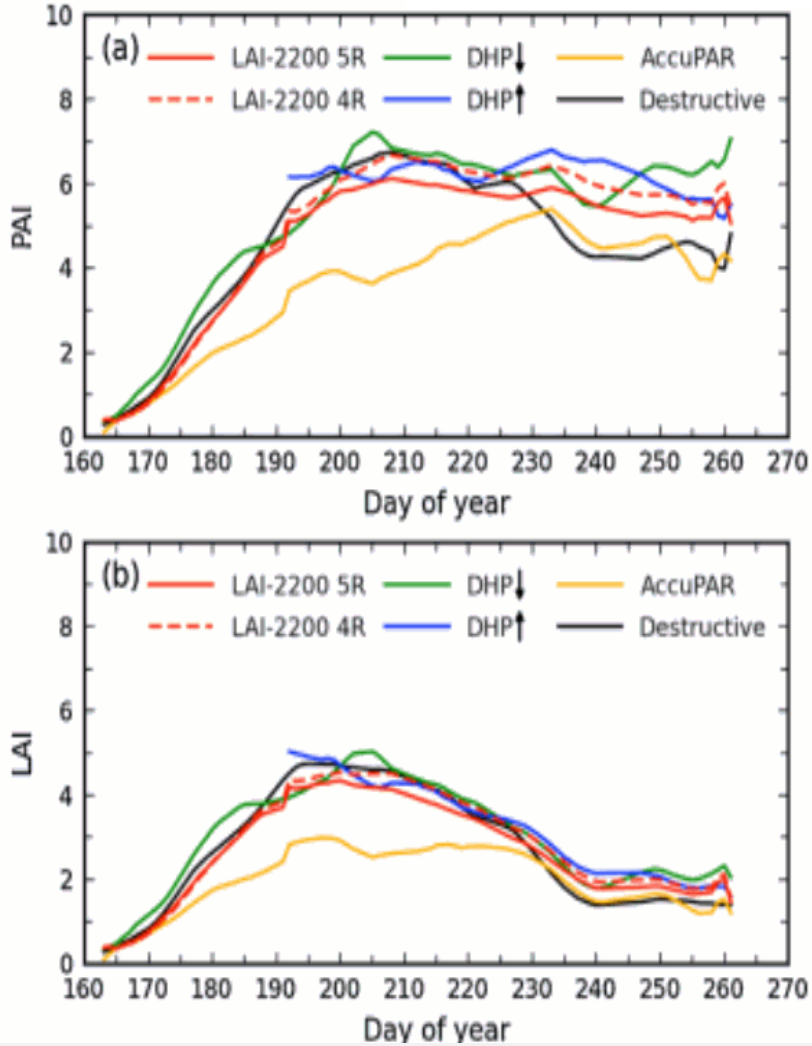
Definition

•**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

GAIeff

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

$$FAPAR^{BS}(\theta_s) = 1 - P_0\cdot(\theta_s)$$

$$FCOVER = 1 - P_0\cdot(0 - 10°)$$

— **LICOR LAI 2200** (Miller's method)

$$\mathrm{PAI_{eff}} = 2\int_0^{\pi/2} -\ln P_o(\theta)\cos\ \theta\sin\theta d\theta$$

- Others: TRAC

2) PAR transmission (ceptometers)

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

$$\mathrm{PAI_{eff}} = \frac{[(1-(1/2k))f_b - 1]\ln\tau}{A(1-0.47f_b)}$$

FAPAR ≈ 1 - Transmittance

- Others: SunScan, Solems PAR

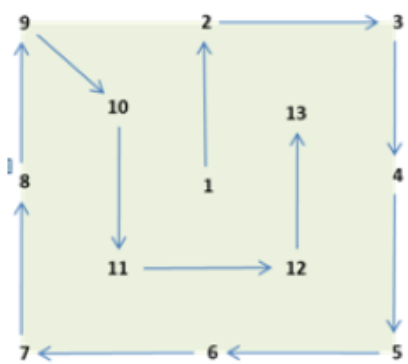
Protocol- Individual LAI sampling

(Elementary Sampling Unit- ESU)

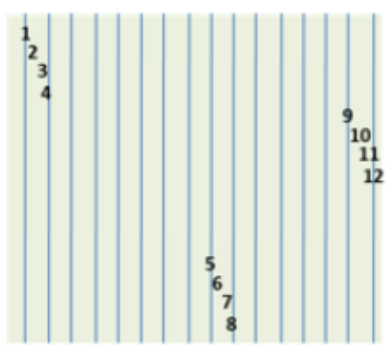
- It is recommended to use indirect methods (DHP is preferred) and to define properly the variable measured related to LAI, i.e., document well the way the LAI is derived for an appropriate LAI definition:
- ***The presence of non-green elements*** and the way it was accounted for or not
- ***The type 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

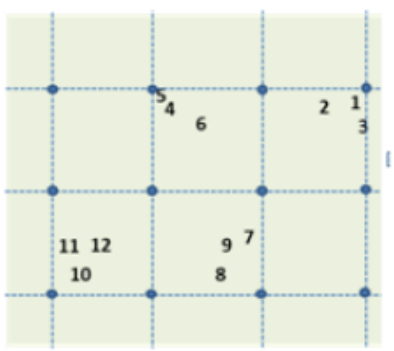
Random – homogeneous



Row crops



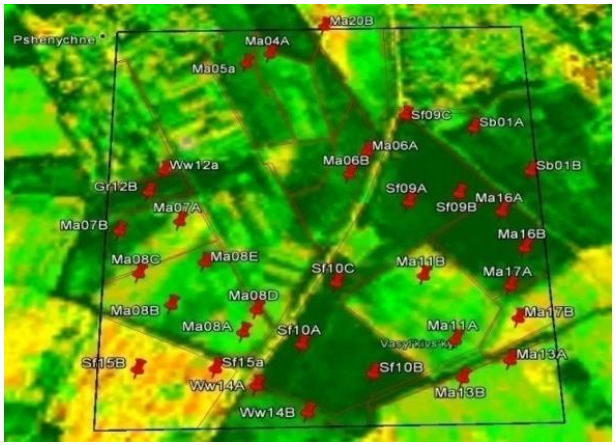
Regular Plantation



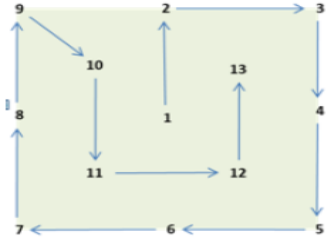
Protocol - Sampling the Site

- ***Size of the site:***
  - 3-km x 3-km
- ***Number of ESUs:***
  - 30 - 50 sampling units
- ***Size of the ESU:***
  - ~ 20 m x20 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)

Sampling the site



Random – homogeneous



Row crops

Regular

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).

Column	Var.Name		Comment
1	Plot #		Number of the field plot
2	Plot Label		Label of the plot
3	ESU #		Number of the Elementary Sampling Unit (ESU)
4	ESU Label		Label of the ESU in the campaign
5	Northing Coord.		Geographical coordinate: Latitude (º), WGS-84
6	Easting Coord.		Geographical coordinate: Longitude (º), WGS-84
7	Extent (m) of ESU (diameter)		Size of the ESU [1]
8	Land Cover		Detailed land cover
9	Start Date (dd/mm/yyyy)		Starting date of measurements
10	End Date (dd/mm/yyyy)		Ending date of measurements
11	LAI	Method	Instrument
12		Nb. Replications	Number of Replications
13		LAIeff	Computed from the gap fraction as a function of t angle
14		Uncertainty	LAIeff standard deviation
15		LAI	LAItrue = LAIeff/clumping index
16		Uncertainty	LAItrue standard deviation
17	FAPAR	Method	Instrument
18		Nb. Replications	Number of Replications
19		FAPAR	Measured daily integrated FAPAR under direct llu conditions at a given solar position
20		Uncertainty	FAPAR standard deviation
21	FCOVER	Method	Instrument
22		Nb. Replications	Number of Replications
23		FCOVER	Retrieved from gap fraction. fCover = 1-Po(0-10º)
24		Uncertainty	FCOVER standard deviation
25	WATER CONTENT	Method	Instrument
26		Nb. Replications	Number of Replications
27		Leaf WC (g/m2)	Leaf WC = (FWT-DWT)/Aleaf
28		Uncertainty	Leaf WC uncertainty
29		Canopy WC (kg/m2)	Canopy WC = leaf WC * LAI
30		Uncertainty	Canopy WC uncertainty
31	CHLOROPHYLL CONTENT	Method	Instrument
32		Nb. Replications	Number of Replications
33		Leaf Ch (microg/cm2)	Leaf Chlorophyll Content
34		Uncertainty	Leaf Chlorophyll Content standard deviation
35		Canopy Ch (mg/m2)	Canopy Chlorophyll Content = leaf Ch * LAI
36		Uncertainty	Canopy Chlorophyll Content uncertainty
37	OTHER	LAI57eff	Effective leaf area index calculated at the 57.5 ze DHP
38		FAPAR (white sky)	white sky (or diffuse) FAPAR
39		FWT (g)	Sample fresh weight. Sample includes aprox. 95% 5% of steams
40		DWT (g)	Sample dry weight
41		Aleaf (m2)	Sample area
42		Unclassified pixels (%)	Unclassified pixels in the estimation of sample are
43	COMMENTS		Additional commets

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

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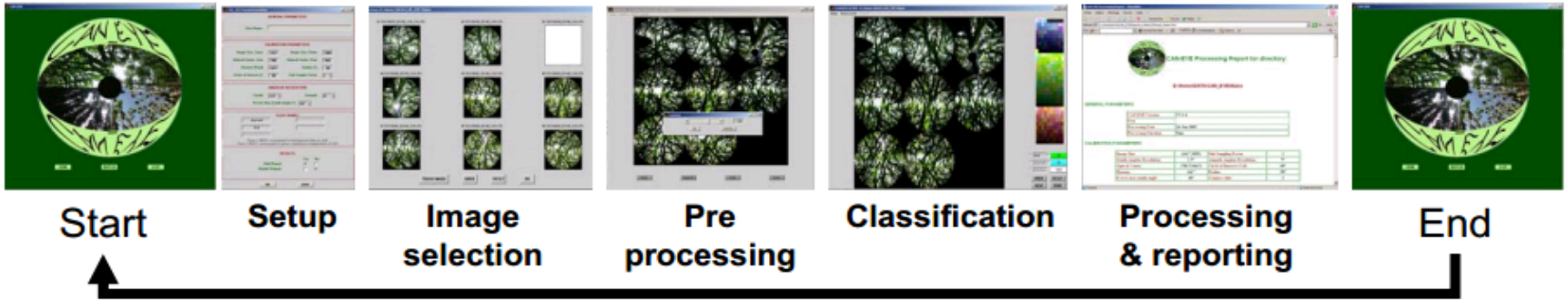
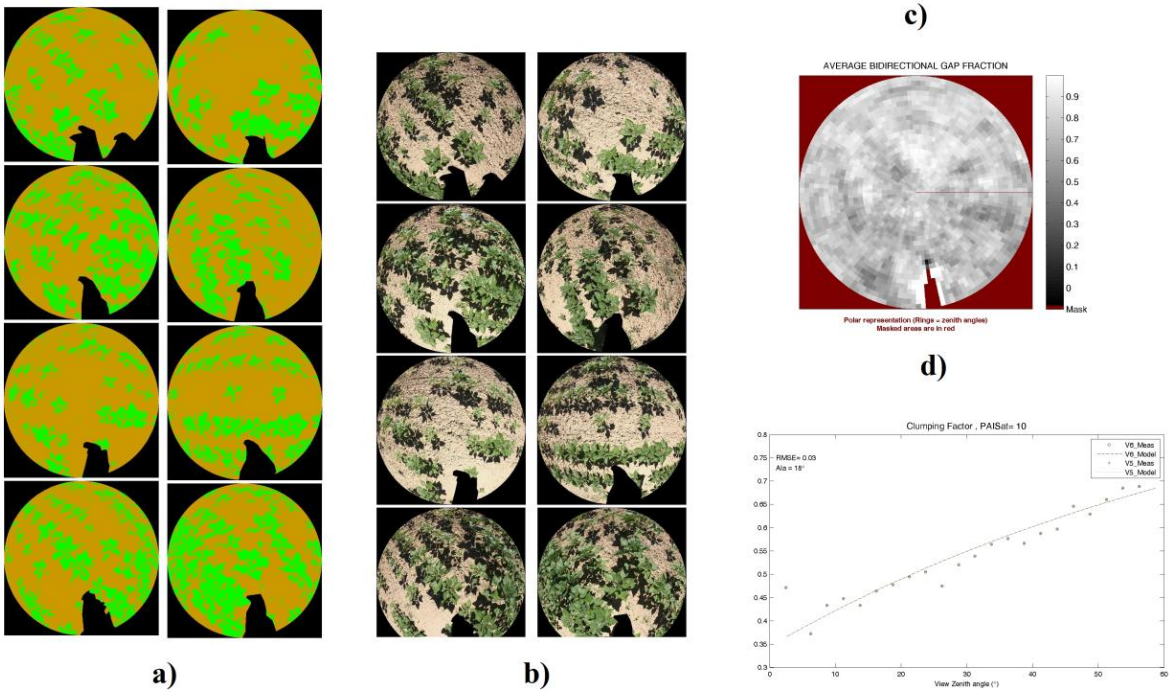
Processing DHP with CAN-EYE



www4.paca.**inra**.fr/**can-eye**



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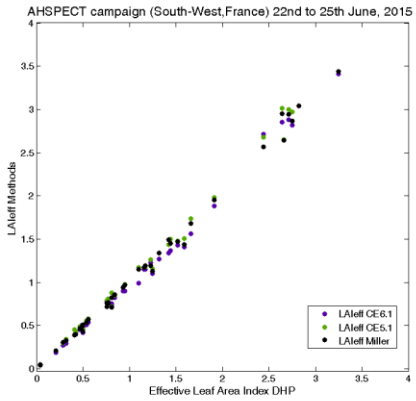
Processing DHP with CAN-EYE

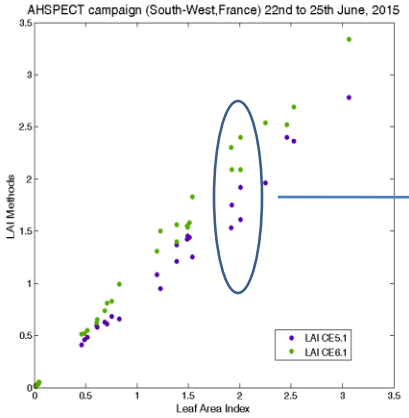
- Three methods are used CEv5.1, CEv6.1, Miller's (LAI-2000)

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

		LAI									
Method	Nb. Replications	LAIeff CEv6.1	LAIeff CEv5.1	LAIeff Miller	LAIeff	Uncertainty	LAI CEv6.1	LAI CEv5.1	LAI	Uncertainty	LAI CE6-CE5
DHP	13	2.55	2.68	2.61	2.61	0.07	4.97	3.65	4.31	0.93	1.32
DHP	13	1.88	1.95	1.95	1.93	0.04	4.01	2.93	3.47	0.76	1.08
DHP	13	2.38	2.53	2.49	2.47	0.08	4.74	3.22	3.98	1.07	1.52
DHP	13	1.88	1.96	1.99	1.94	0.06	3.85	3.45	3.65	0.28	0.40
DHP	13	2.29	2.38	2.34	2.34	0.05	4.65	3.25	3.95	0.99	1.40
DHP	13	2.34	2.39	2.34	2.36	0.03	4.94	3.46	4.20	1.05	1.48
DHP	13	2.38	2.63	2.5	2.50	0.13	4.69	4.34	4.52	0.25	0.35
DHP	13	2.21	2.26	2.25	2.24	0.03	4.34	3.92	4.13	0.30	0.42





Clumping estimate uncertainties

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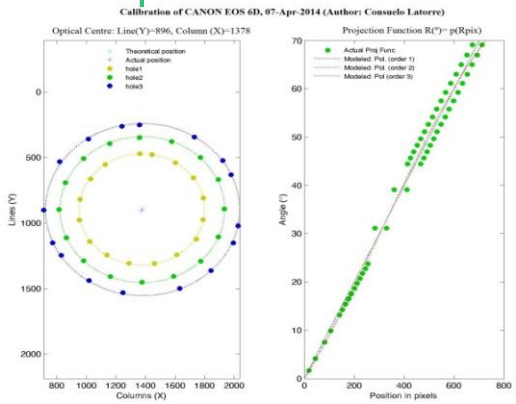
DHP calibration (CAN-EYE)

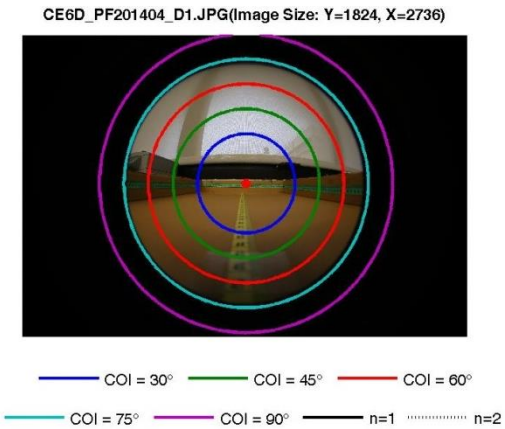
Optical centre and Projection Function

Alignment

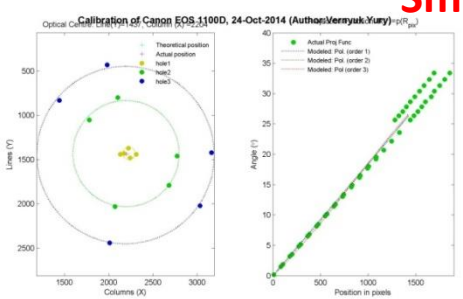
Optical centre

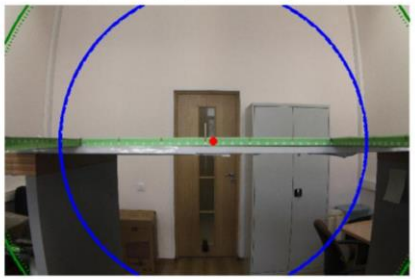


Projection Function



Small FOV





Example for EOLAB system and camera from TULA site

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Special cases

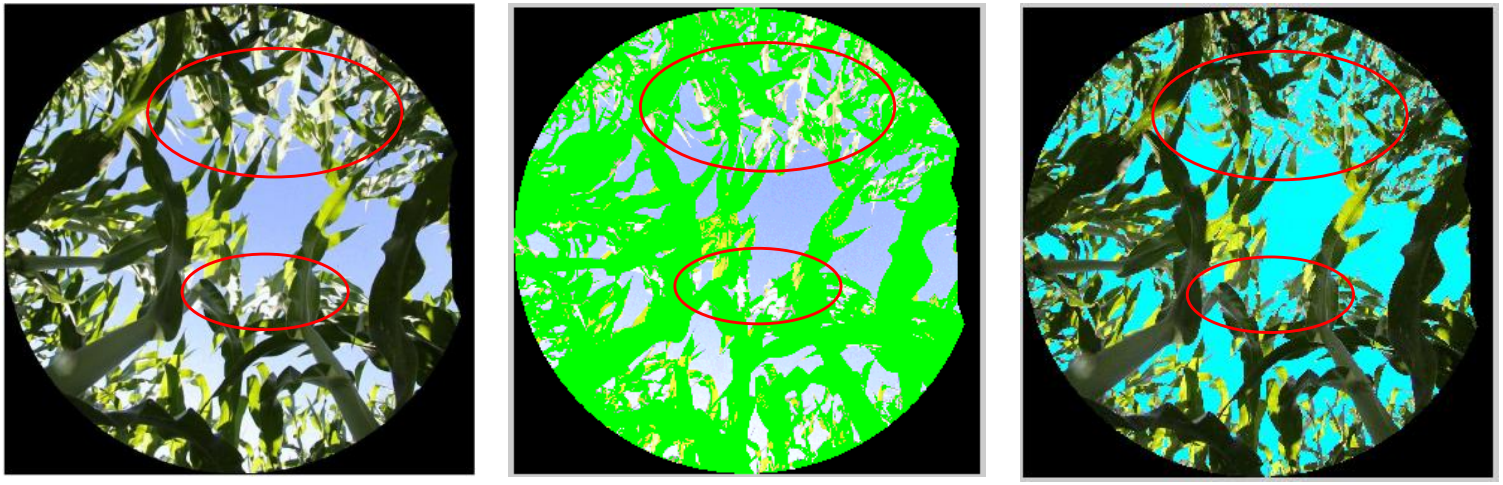
- Heterogeneous ESUs

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



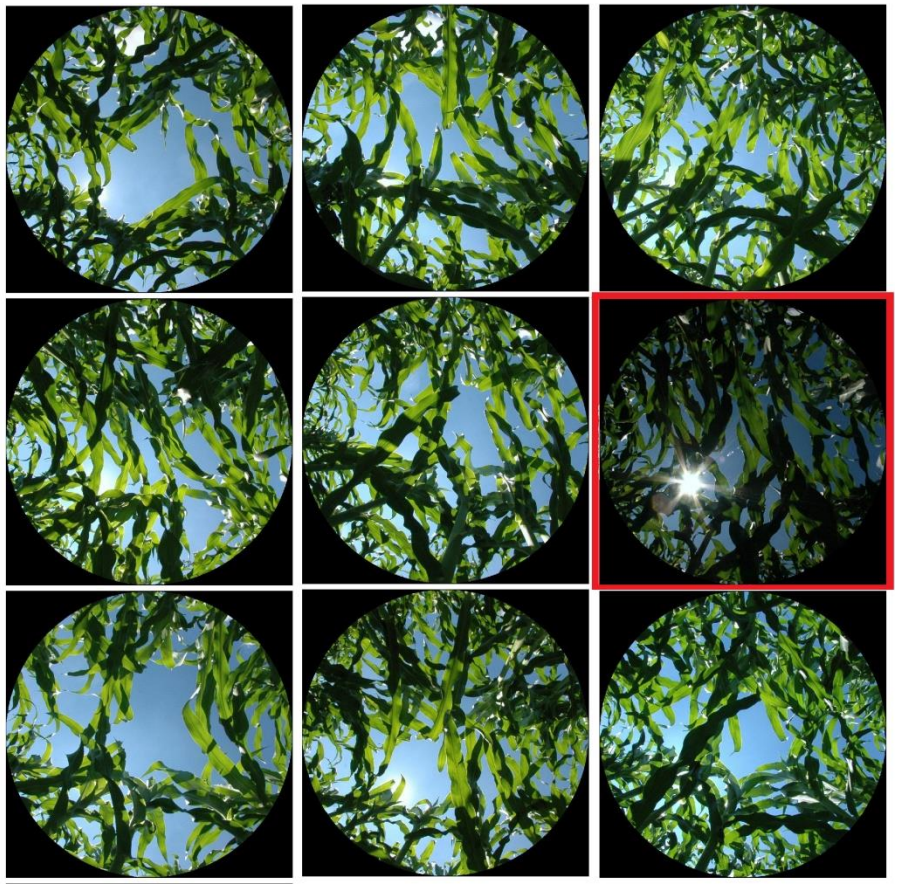
To process the ESUs twice (one classifying vegetation and other classifying sky/soil, and provide the average

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 clumpling 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

Papaver Somniferum

Clumping 0.68

Special cases

- Plots with understory/overstory
  - $LAI = LAI_{ABOVE} + LAI_{BELOW}$
  - $FCOVER = 1 - (1 - FCOVER_{ABOVE}) \cdot (1 - FCOVER_{BELOW})$
  - $FAPAR = 1 - (1 - FAPAR_{ABOVE}) \cdot (1 - FAPAR_{BELOW})$

Summary

- Standard procedurce for in-situ LAI collection has been stablished 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 Idex, 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 pprocessing shall be performed by trained people, ootherwise ccould lead to important errors (up to 1 in LAI), or even grater in particular cases. For difficult cases, process ttwice 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.***
- ***O On-going collaboration with few JECAM sites***.

Thank you for your attention

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