Suivi de la végétation à partir de mesures de transmittance

F. Baret
INRA Avignon

Loi de Beer/Poisson

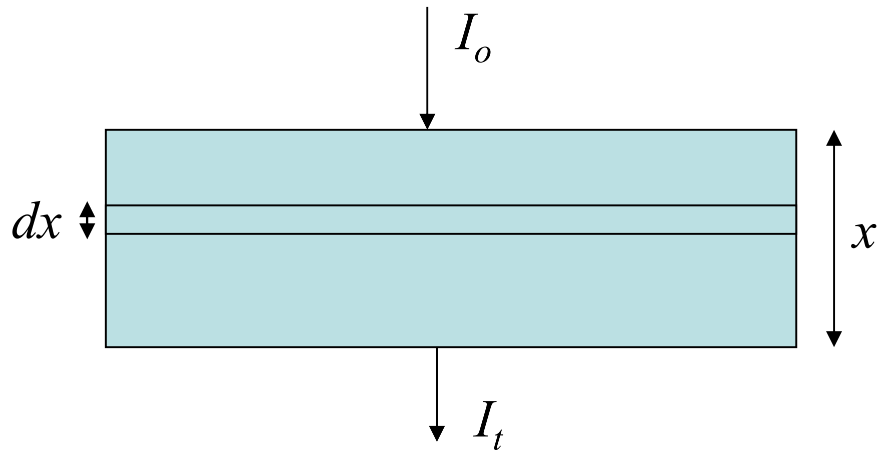
Transmission dans un mileu homogène purement absorbant

Coefficient d'extinction

$$dI = -I \cdot k \cdot dx$$

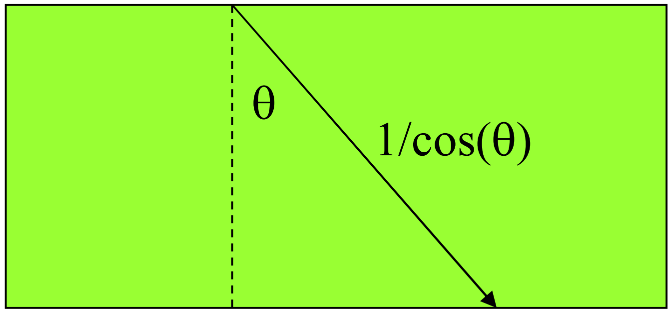
$$I_t = I_o \cdot e^{-k.x}$$

$$T = \frac{I_t}{I_o} = e^{-k.x}$$

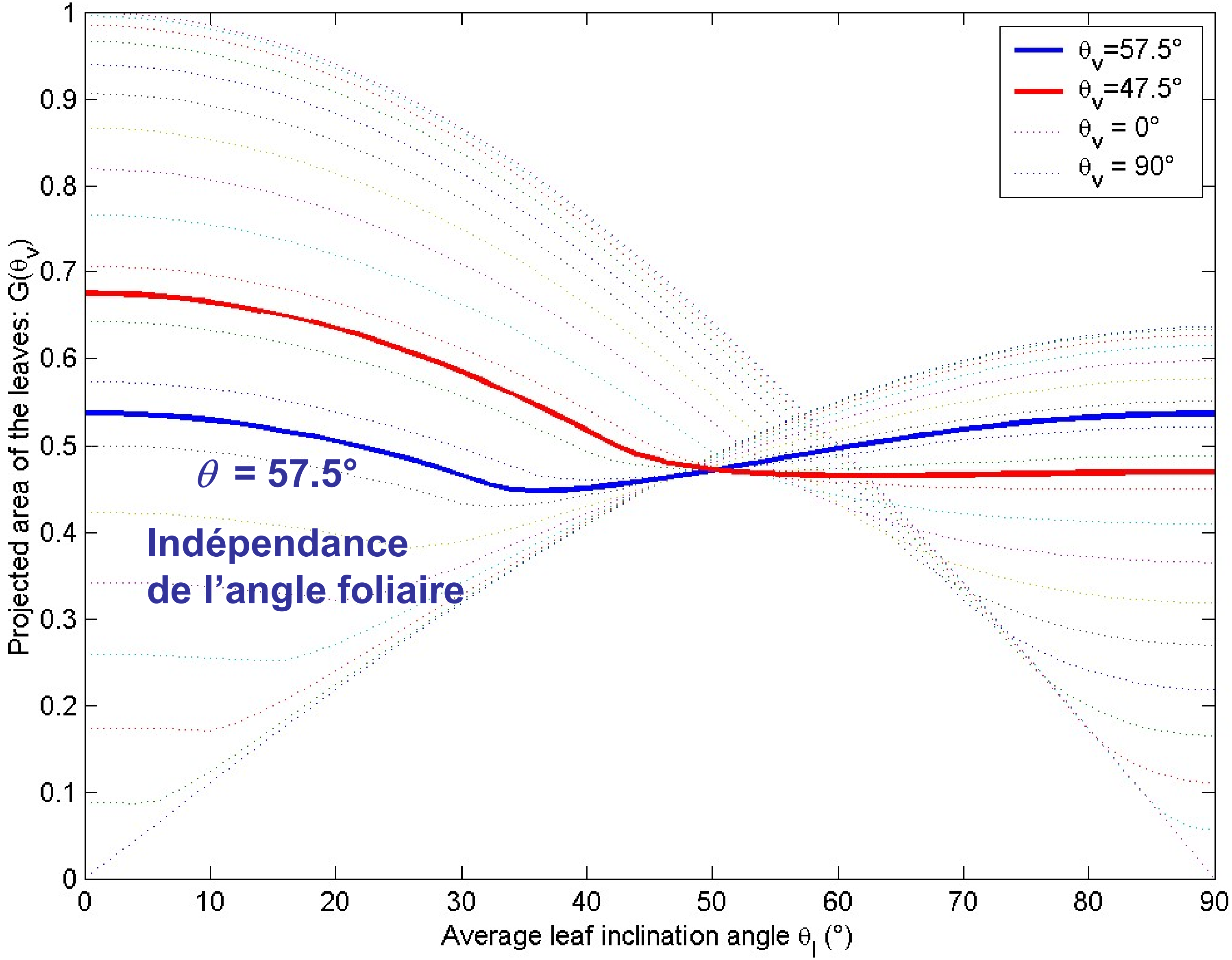


Interet de la mesure de la fraction de trous (transmission)

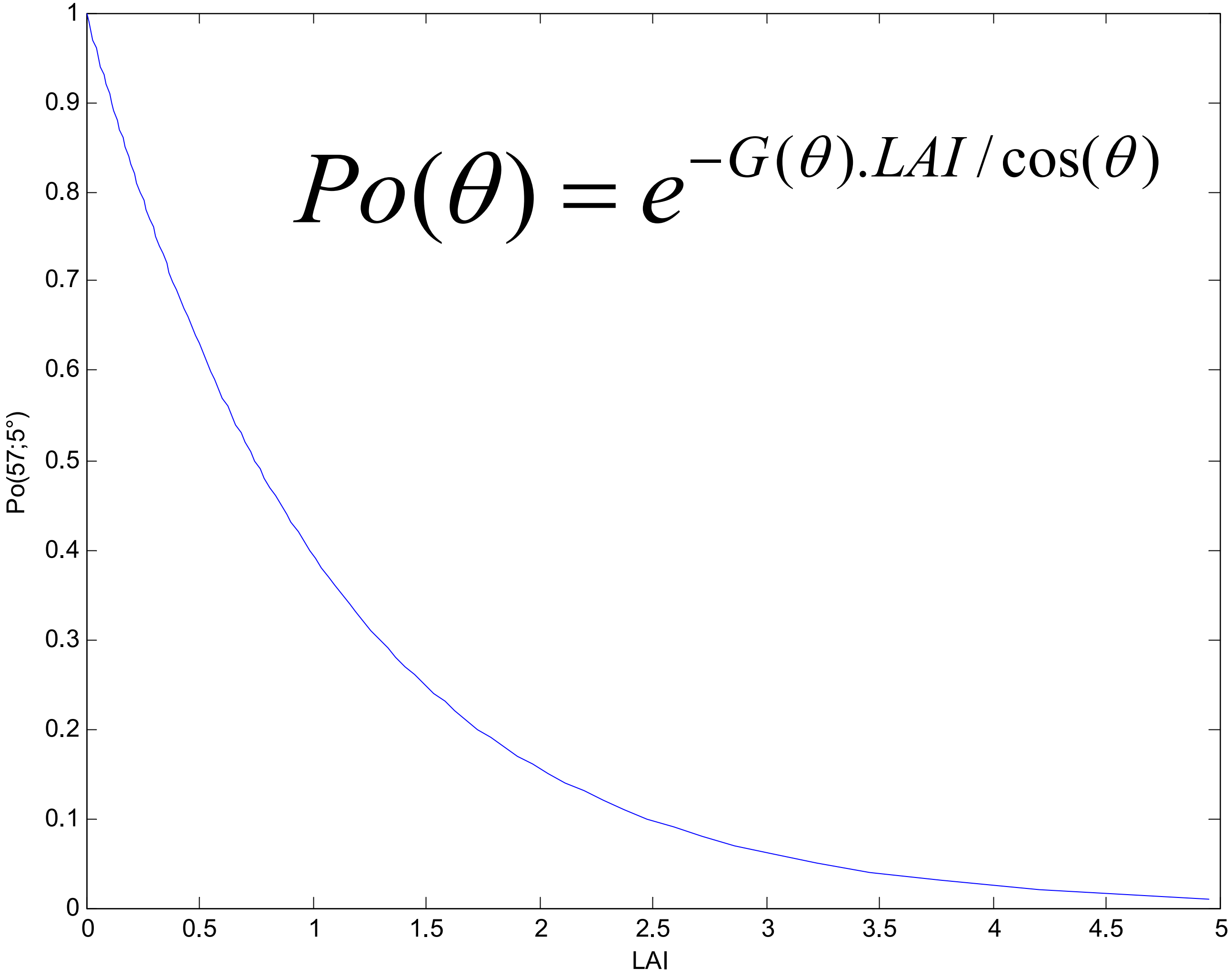
- fCover= $1\text{-}Po(0)$
- fAPAR(θ_s)≈fIPAR(θ_s)=$1\text{-}Po(\theta_s)$
- $$Po(\theta) = e^{-k.LAI} \qquad k = \frac{G(\theta, \theta_l)}{\cos(\theta)}$$



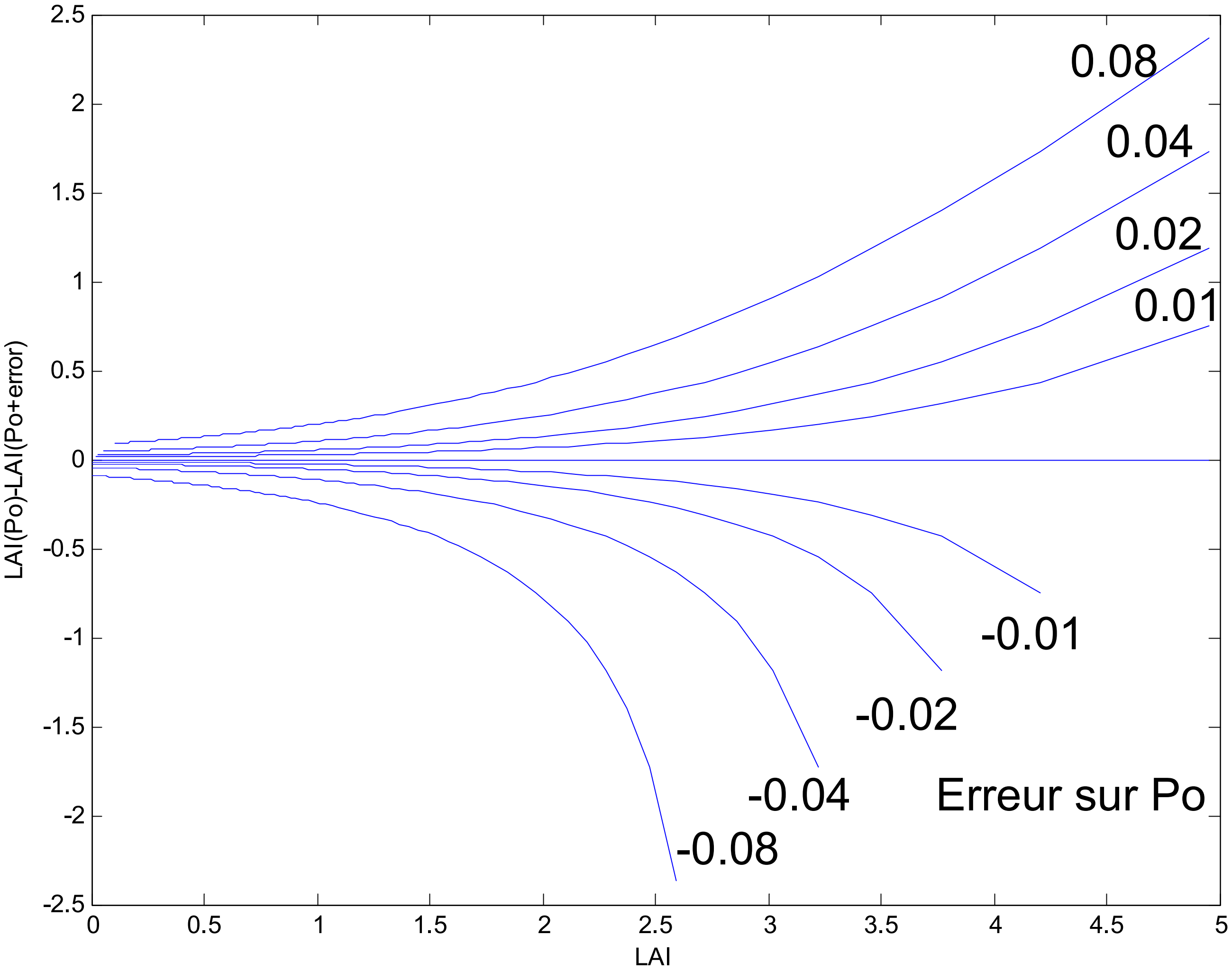
Fonction de projection $G(\theta)$



Relation entre GAI et Po

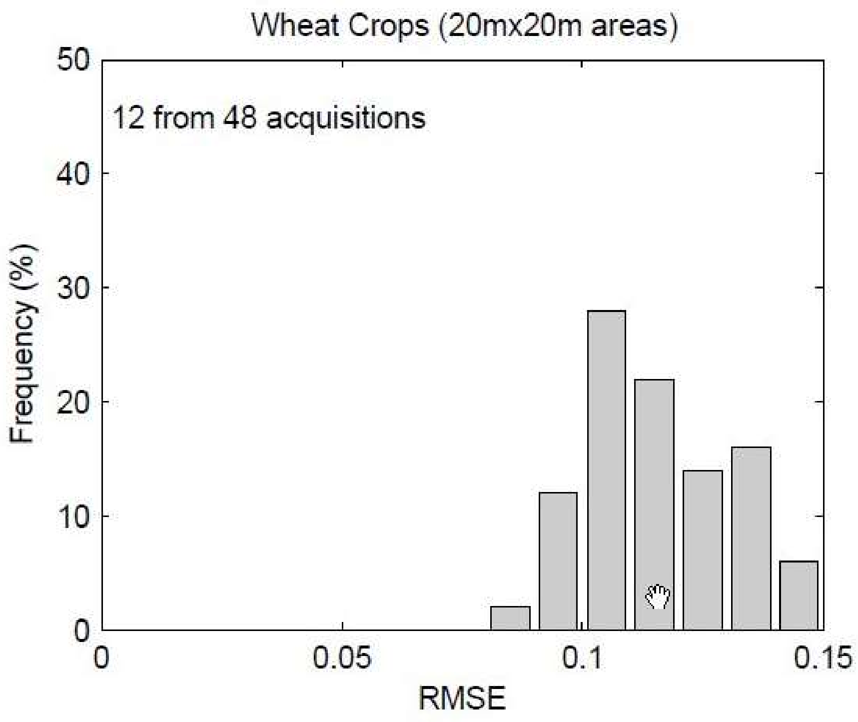


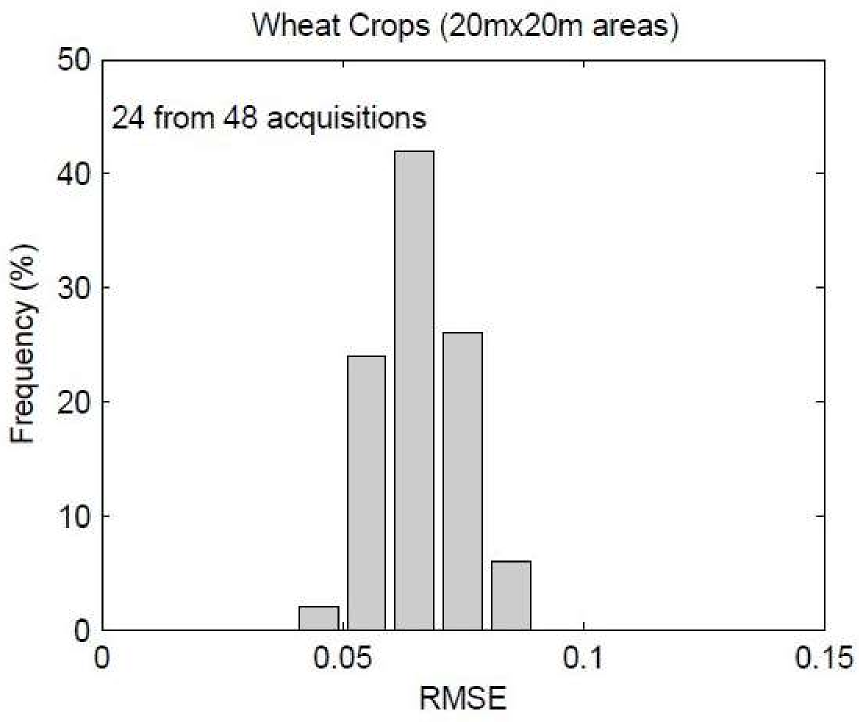
Erreur sur l'estimation du LAI



Echantillonnage spatial

Entre 5 et 15 points de mesures sont nécessaires pour représenter une surface de 10-20 m de coté
Bien prendre en compte l'effet de rang (transects en diagonale).





Les instruments de mesure

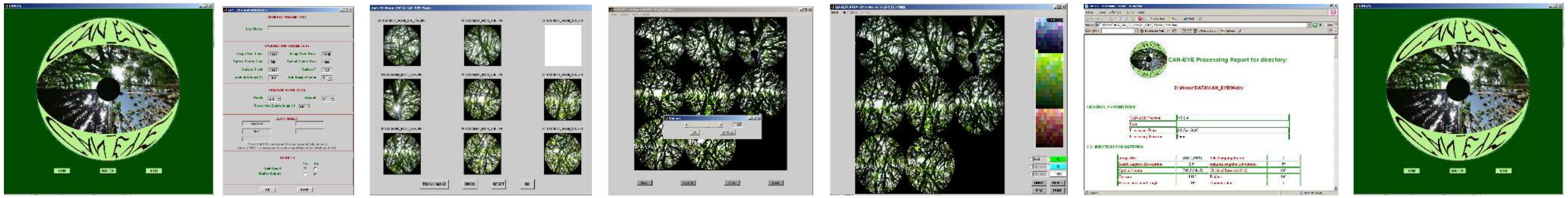
Comparison between instruments allowing indirect LAI measurements

System	Illumination conditions	Spectral domain	No. of zenith angles	Azimuthal coverage	Gap size distribution	Reference readings	Post-processing	Computer resources
DEMON	Direct	430 nm	–	–	No	Yes	No	Low
Sunfleck ceptometer	Diffuse, direct	PAR	–	–	Yes	Yes	Yes	Low
AccuPAR	Diffuse, direct	PAR	–	–	Yes	Yes	No	Low
LAI-2000	Diffuse	<490 nm	5	Full range selectable by hardware	No	Yes	No	Low
Tracing Radiation and Architecture of Canopies (TRAC)	Direct	PAR	–	–	Yes	Yes	No	Low
Hemispherical Cameras	Diffuse, direct	Selectable	Full range	Full range selectable by software	Yes	No	Yes	High
Multiband Vegetation Imager (MVI)	Diffuse	VIS and NIR	Full range	Full range	Yes	No	Yes	High
Ideal device	Diffuse and direct	VIS and NIR	Full range	Full range selectable by software	Yes	No	–	–

Intérêt de la photographie hémisphérique:

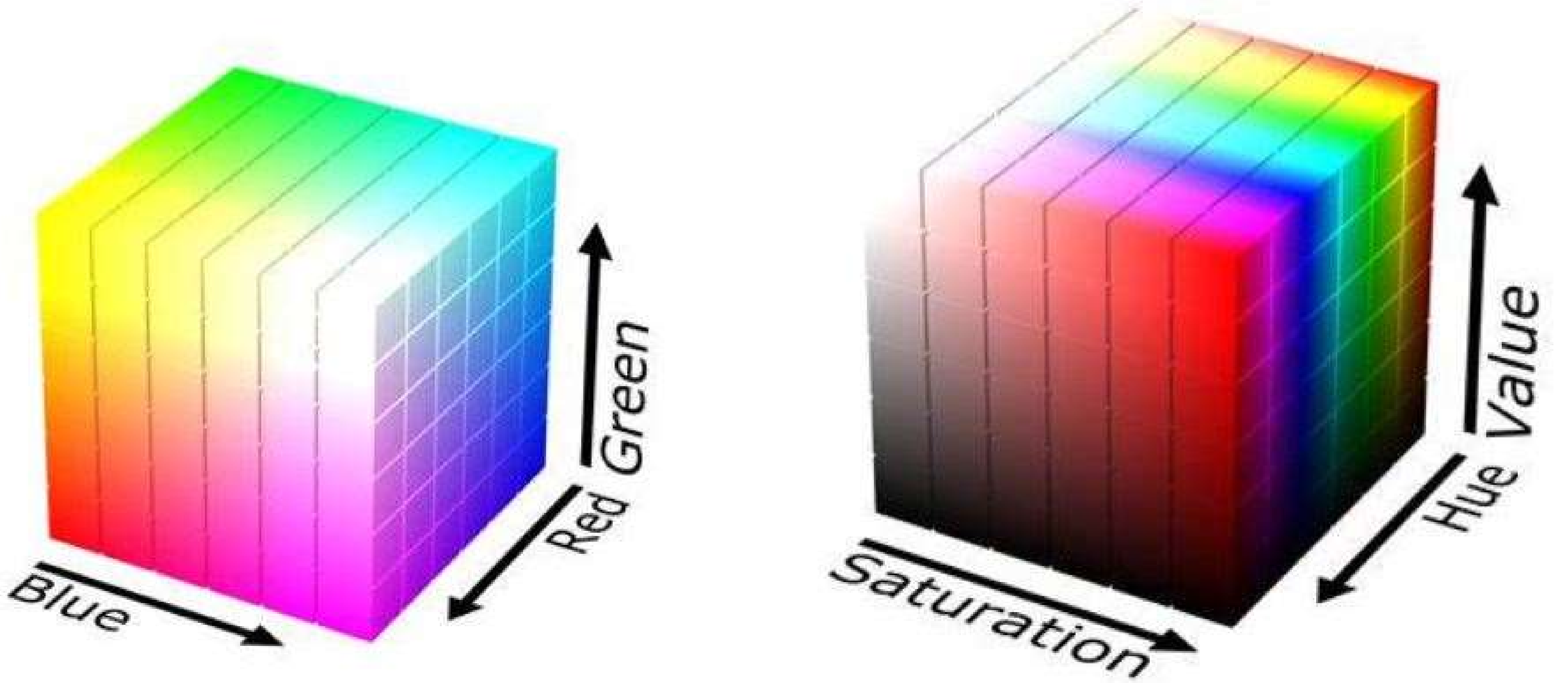
- Peu coûteuse (appareil+fish-eye<1000 euros)
- Facile à mettre en œuvre (conditions d'éclairement)
- Pas de mesures de référence
- Possibilité de mesures sur couvert très peu développés
- Possibilité de contrôle de la qualité des mesures (images)
- Possibilité de distinction d'éléments non verts
- Possibilité de calcul de l'agrégation

CAN_EYE: les différentes étapes



Start — Setup — Image selection — Pre processing — Classification — Processing & reporting — End

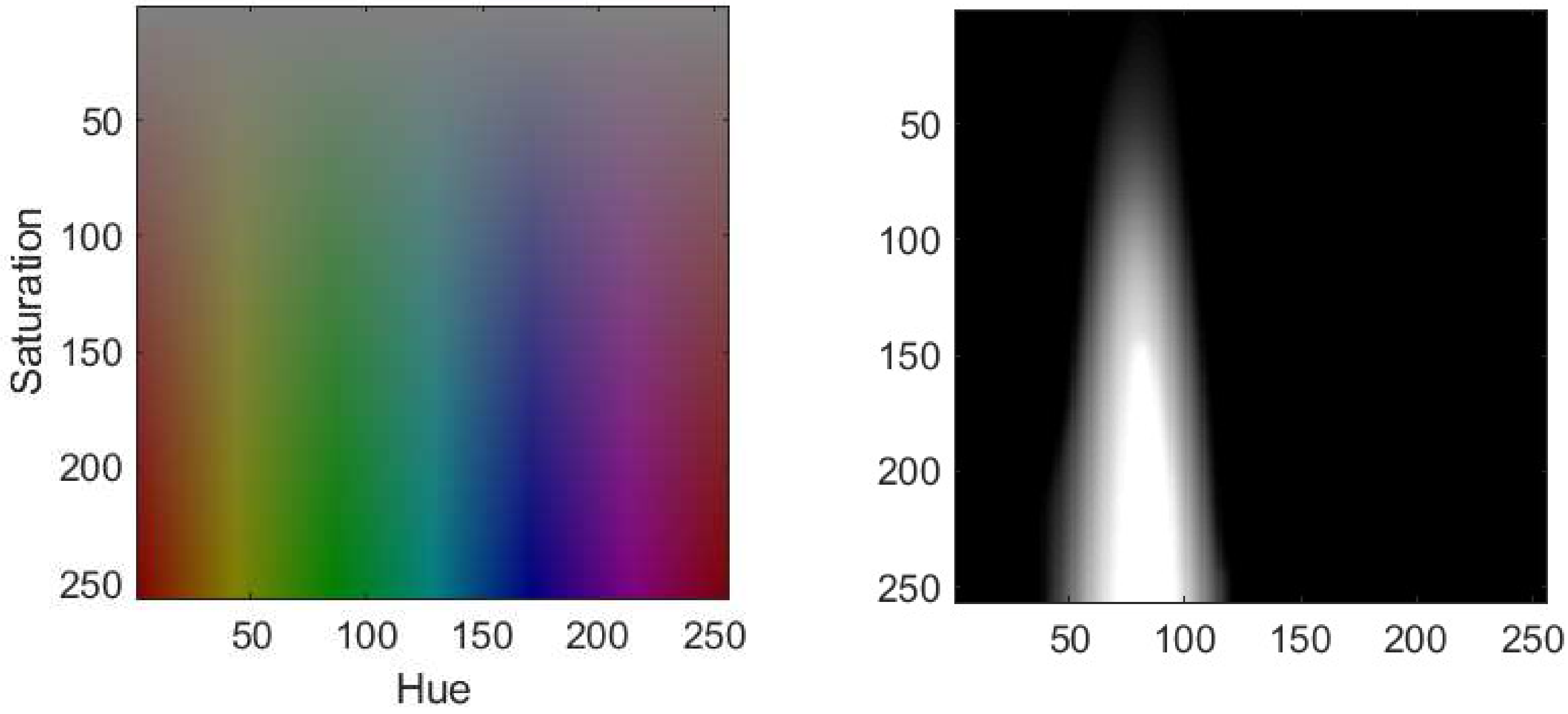
Green segmentation



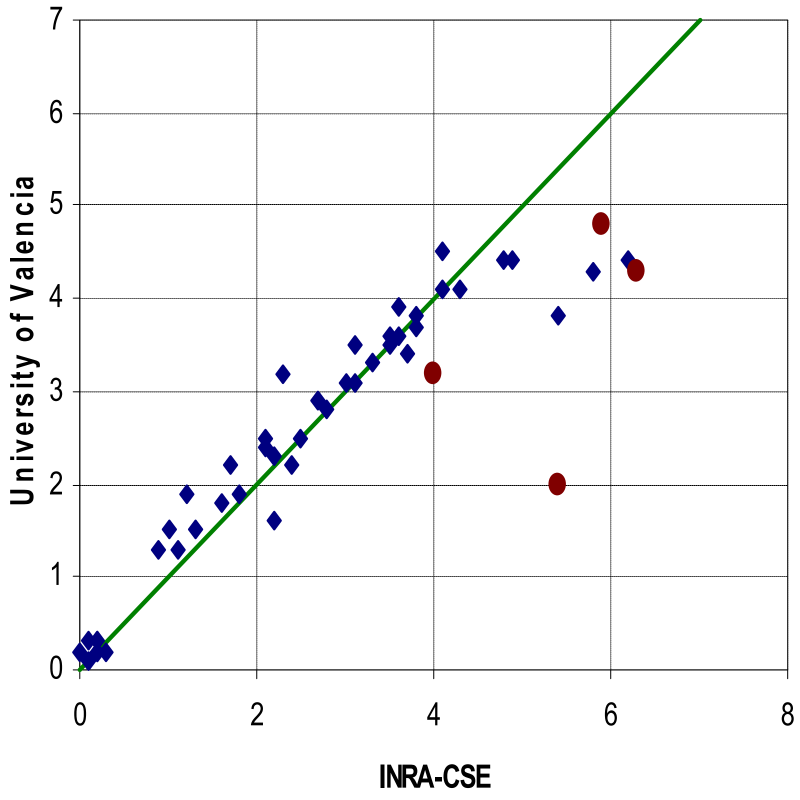
Classical methods for green segmentation

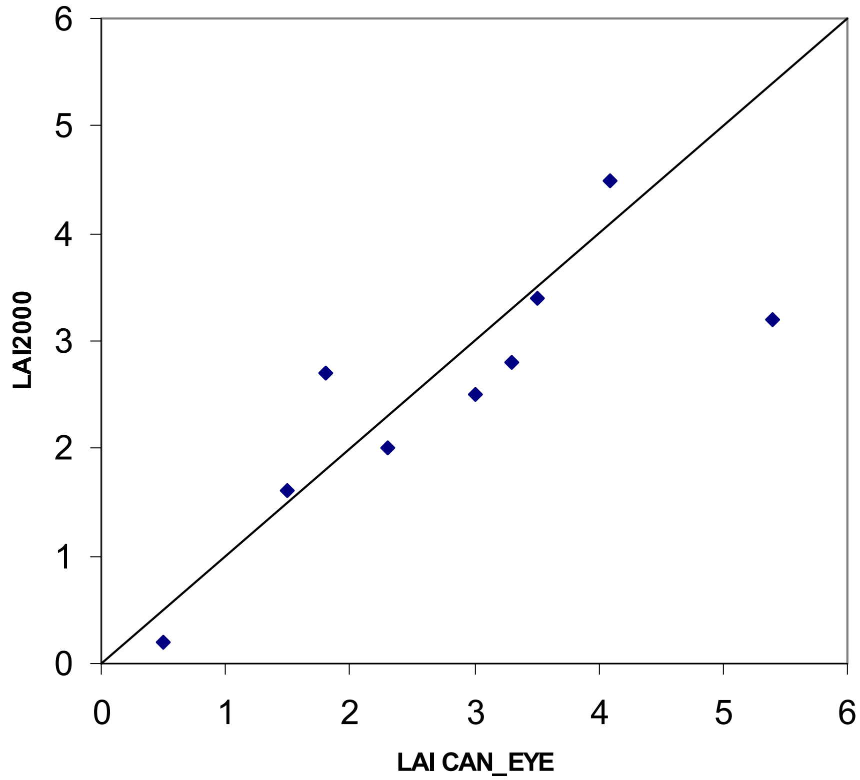
- **Thresholding a color index.**
  - Color indices. Several color indices have been proposed
    - Excess Green, with mainly two main formulations:
      - Absolute formulation: ExGa=2G-R-B Woebbecke et al. 1995 ; Garcıa-Santillan 2017
      - Relative value: ExGr=(ExGa)/(R+G+B) Meyer, 2008; Gee, 2008;
    - ExR=(1.4R-B)/(R+G+B)
    - ExGr-ExR Meyer, 2008;
    - NDI=(G-R)/(G+R) Perez et al. (2000) ; Hunt et al. (2005)
    - VARI=
    - CIVE & VEG Guijarro, 2010; Hague, 2006
    - HSV or LAB YES color space transformation (Gnädinger, 2017; Lootens, 2016 Saber, 1996
    - RDC (Reduced Dimension Clustering): Kmeans from distances to main lines in the RGB space (Steward, 2004)
    - Modified Hue
    - i1i2i3 or (i1i2i3)new (Philipp, 2002)
  - Thresholding.
    - Optimized by training (Meyer, 2008)
    - Otsu automatic thresholding was used in most cases (Meyer, 2008)
    - Adaptive threshold (Saber, 1996)
- **Training a machine learning:**
  - random forest Guo, 2013
  - SVM
- **3D color space segmentation** Hemming, 2000

Discrimination dans le plan Saturation / Hue

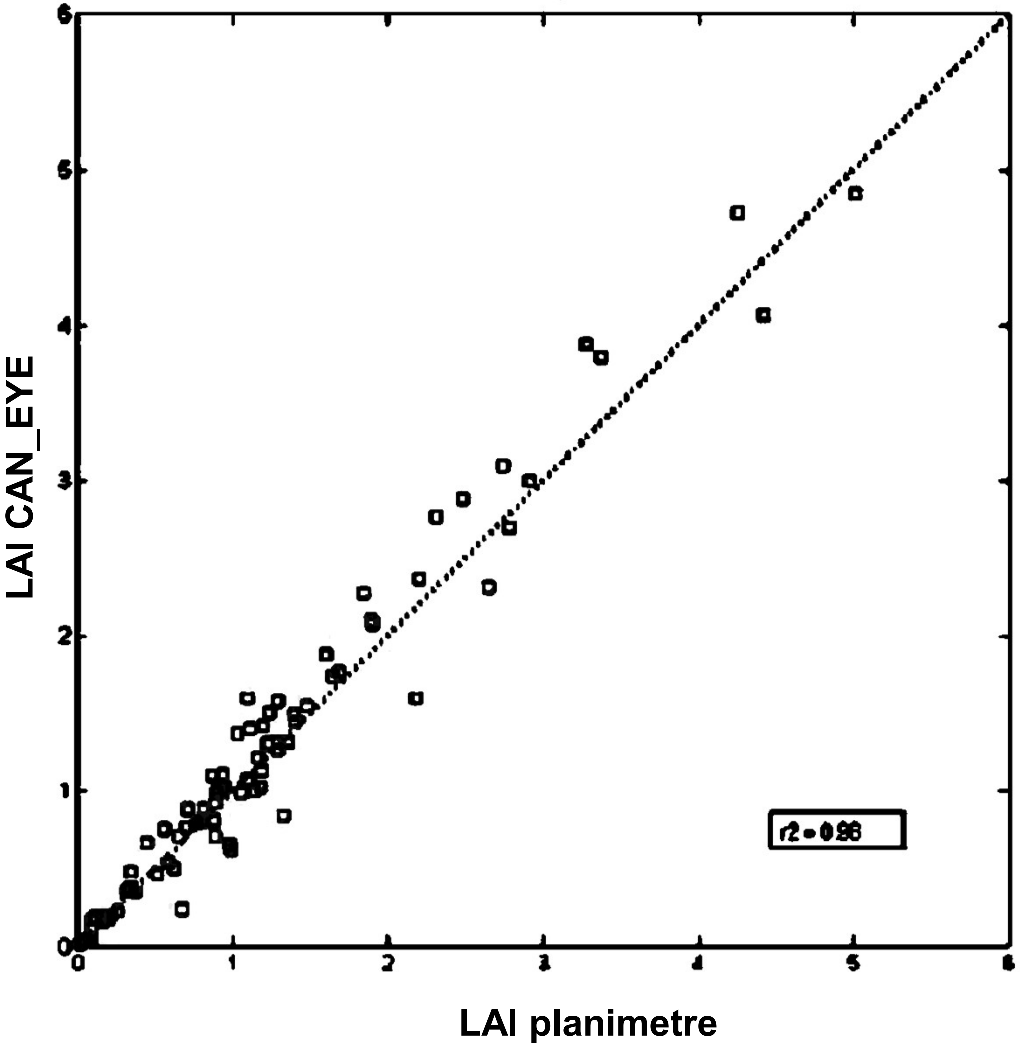


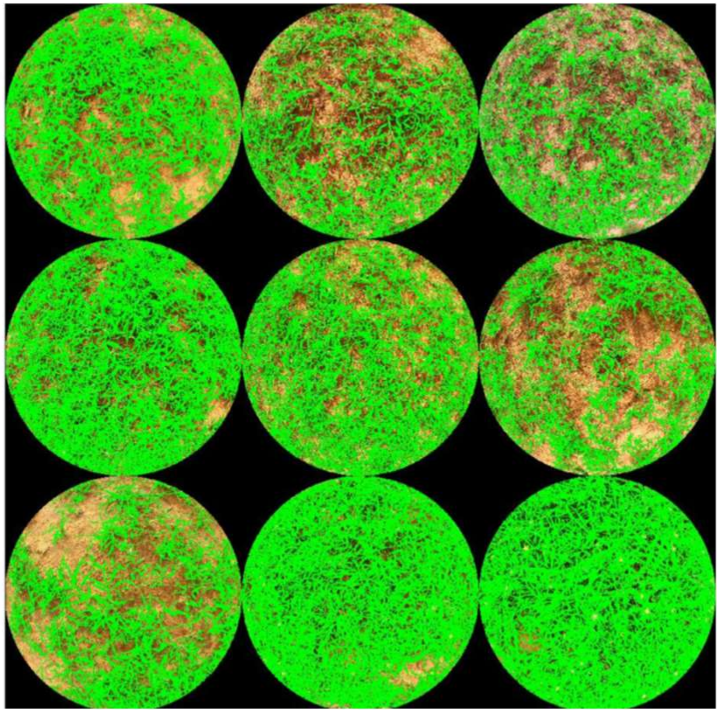
Résultats 1/3: Barrax



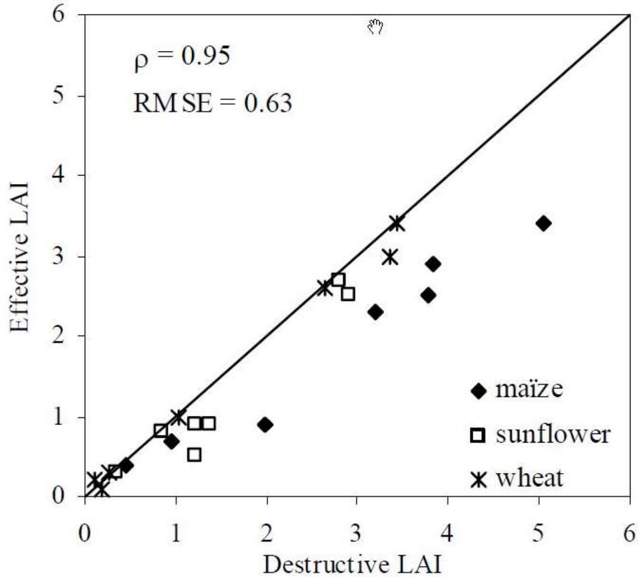


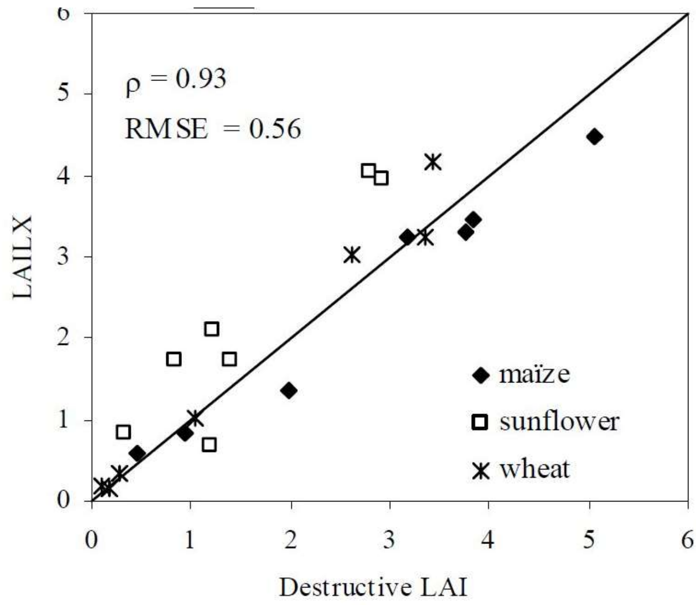
Resultats 2/3: Mali

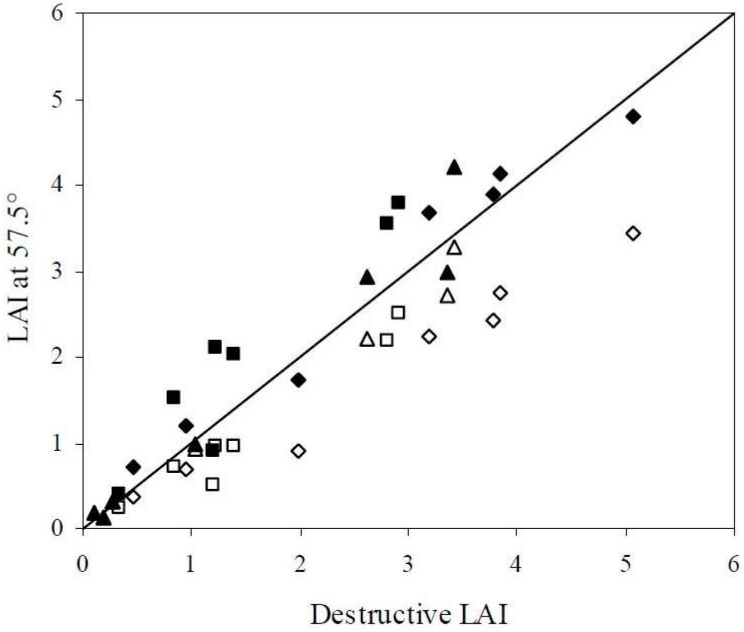




Resultats 3/3: Sud-ouest







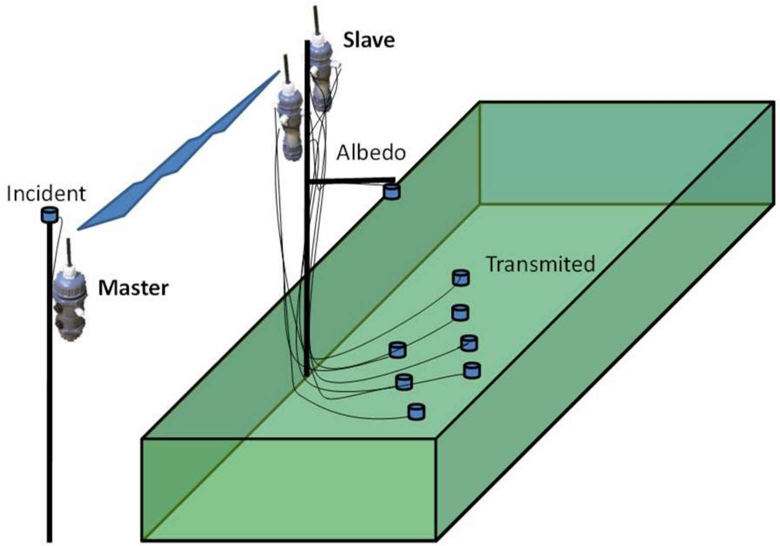
P@rameters

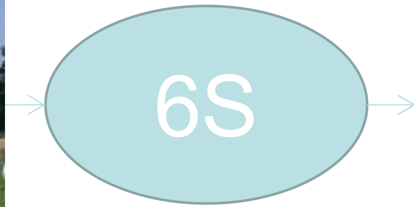
Criterions	Hemispherical PAR sensors	Directional blue photodiode sensors
PAI estimates	Yes	Yes
PAR measurement	Yes	No
Albedo measurements	Yes	No
Sensitivity to illumination conditions	Yes (sun position, diffuse fraction)	No
Sensitivity to leaf clumping (for PAI estimates)	Yes	restricted
Spatial sampling	Larger (±90°)	Restricted (±20°)
Cost	50€	25€

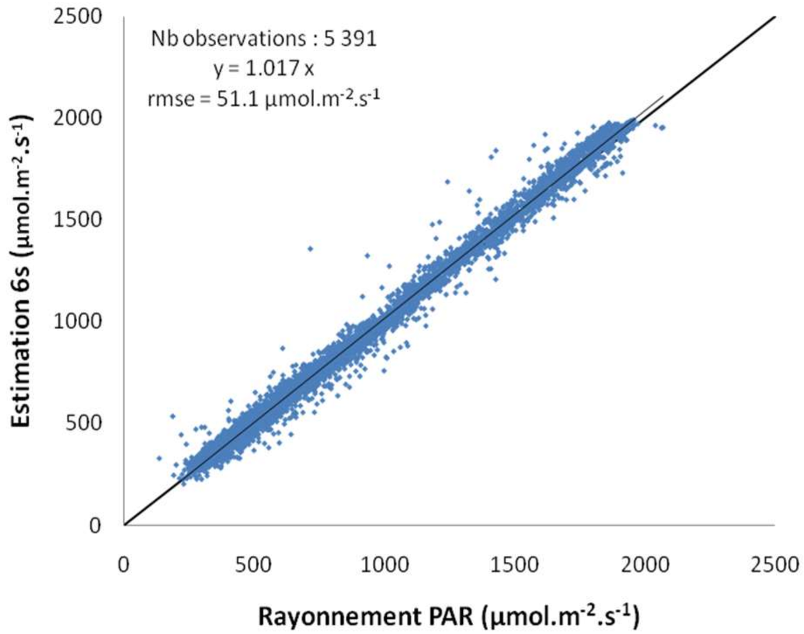
PAR@METER

- Better suited for agriculture



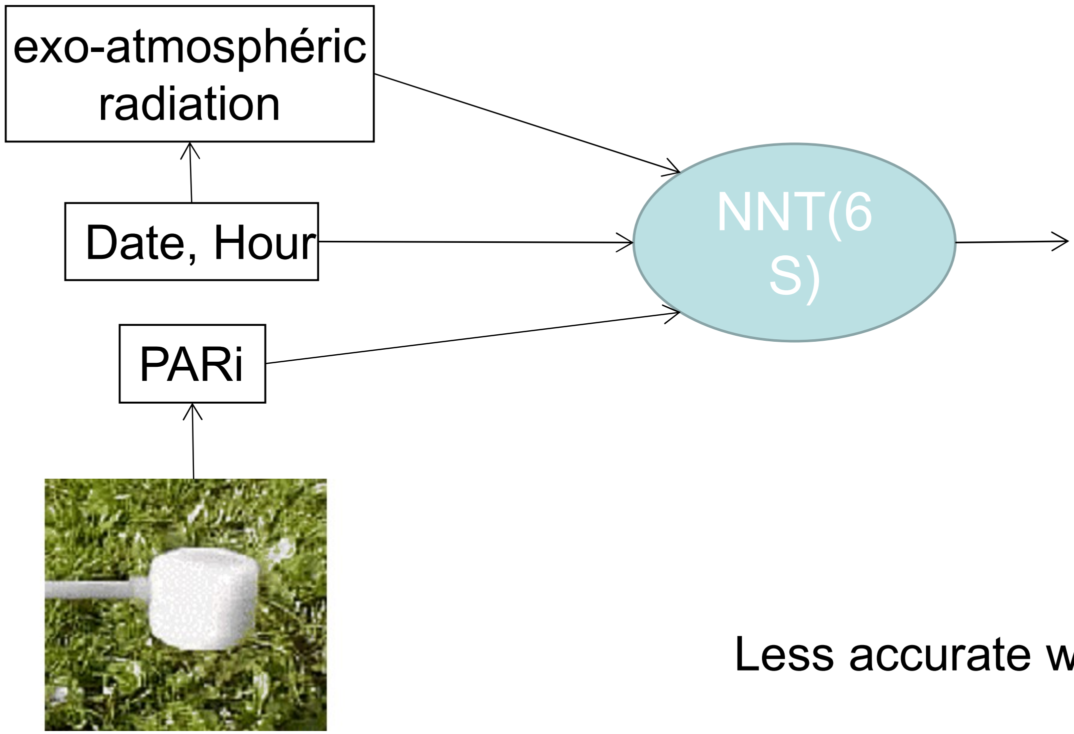
Absolute calibration based on AERONET measurements

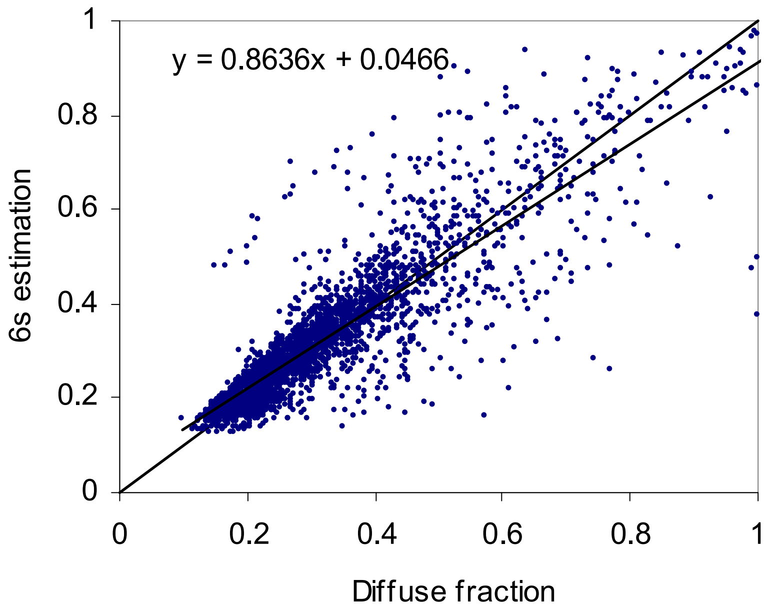




Absolute calibration needed
for diffuse fraction estimation

Estimates of the diffuse fraction from irradiance measurements based on 6S model simulations





Less accurate when partially cloudy sky

PAI estimation

$$[\tau] = [f] \cdot e^{-K(ALA,h) \cdot PAI} + (1 - [f]) \cdot e^{-K(ALA,[\theta]) \cdot PAI}$$

- $[\tau]$: Transmittance PARt/PARi
- $-K(ALA,h)$: Hemispherical extinction coefficient
- $[f]$: Diffuse fraction
- $-K(ALA,[\theta])$: Directionnal extinction coefficient

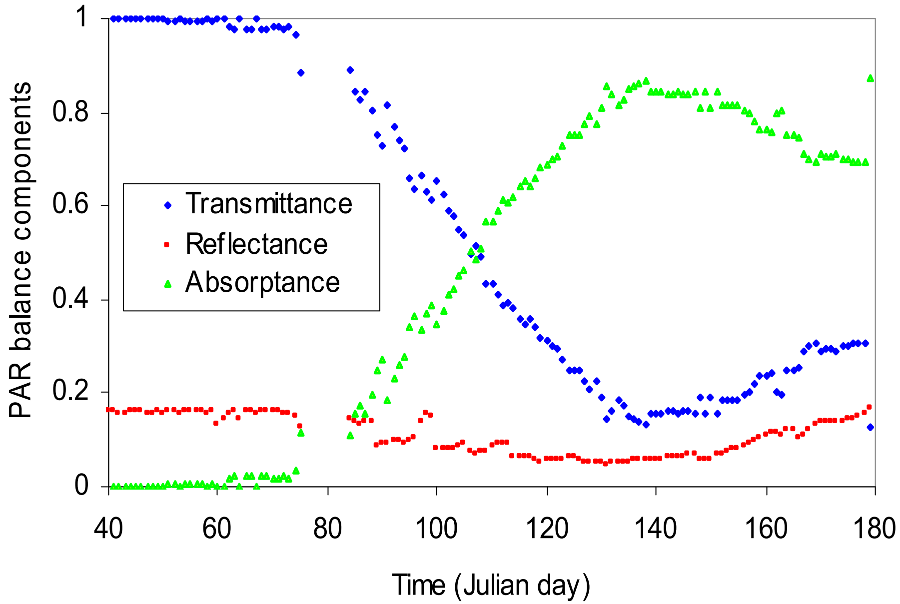
Adjusting ALA and PAI over a temporal window of few days

$$J = \sum_{1}^{n} \omega \cdot (\tau - \hat{\tau})^2 + J_{prior}$$

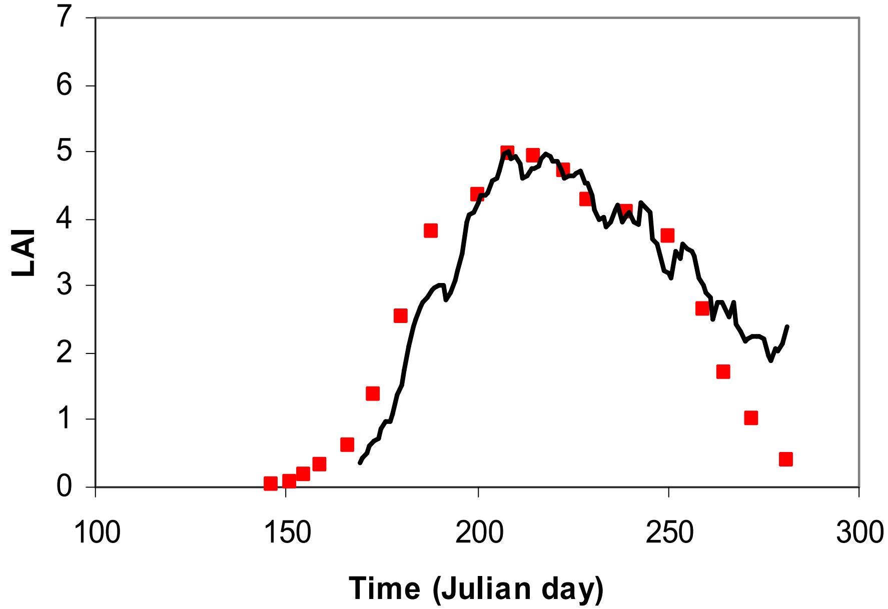
The Poisson model is currently used under randomly distributed vegetation elements
The radiative transfer model may be refined for specific vegetation types

Additional results

PAR balance over Wheat crop



LAI dynamics over maize crops



LAI: several definitions

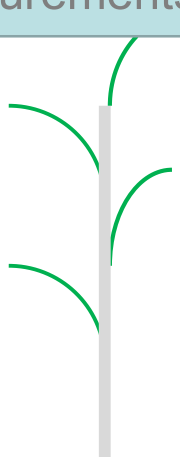
Destructive measurements

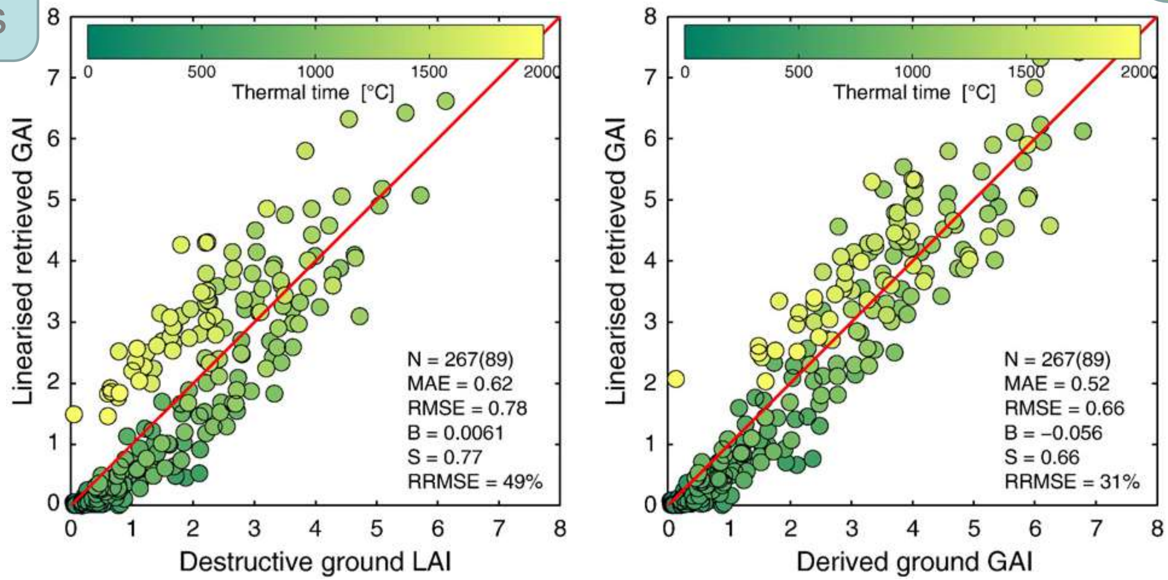
	Only leaf	All vegetation elem.
Green+non green	LAI	PAI
Green	GLAI	GAI

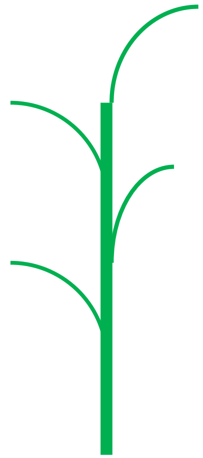
Upward looking Indirect methods

downward looking Indirect methods Incl. Remote Sensing

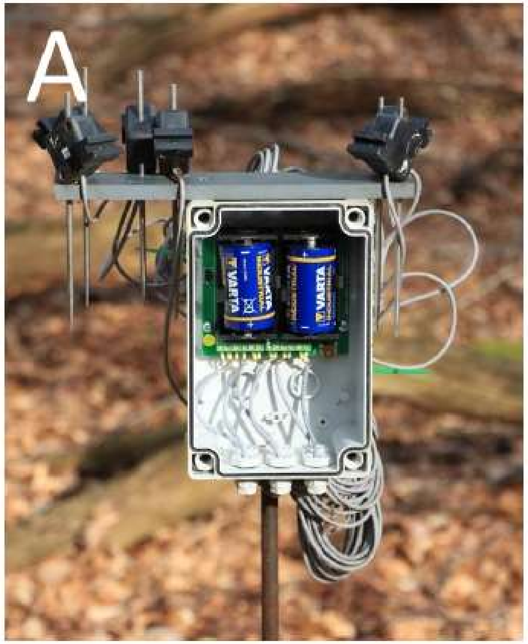
Destructive measurements







PASTIS 57°



remote sensing

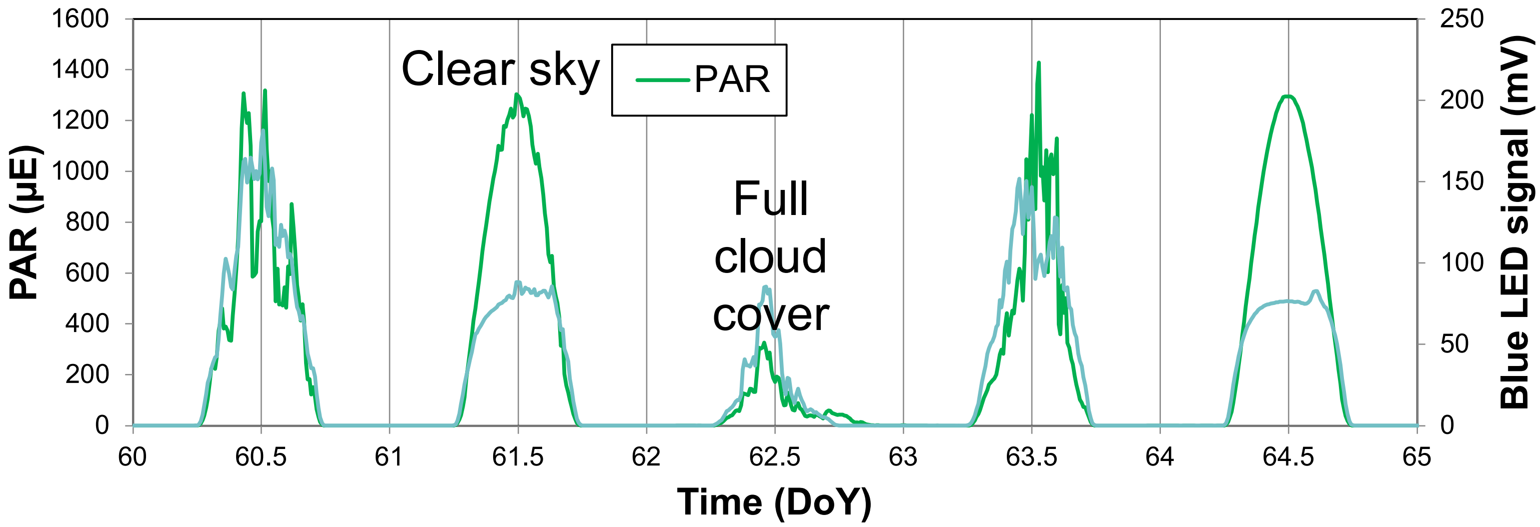
MDPI

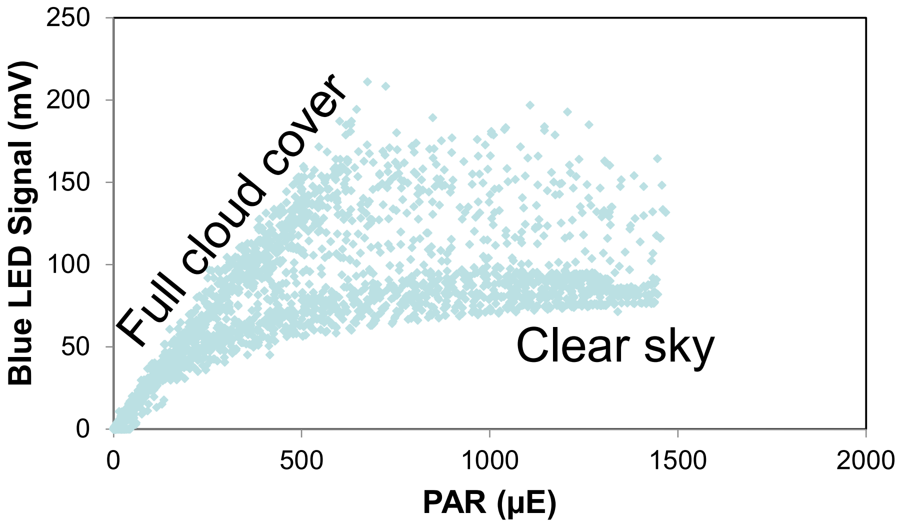
Article

Monitoring Forest Phenology and Leaf Area Index with the Autonomous, Low-Cost Transmittance Sensor PASTiS-57

Benjamin Brede [1,*], Jean-Philippe Gastellu-Etchegorry [2], Nicolas Lauret [2], Frederic Baret [3], Jan G. P. W. Clevers [1], Jan Verbesselt [1] and Martin Herold [1]

Comparison with PAR sensors



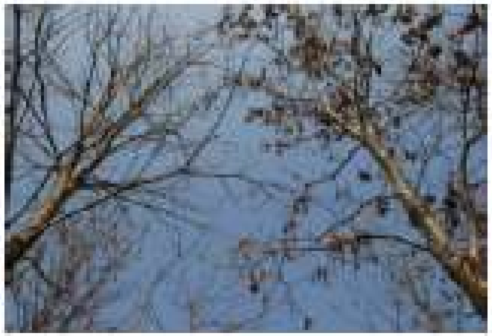


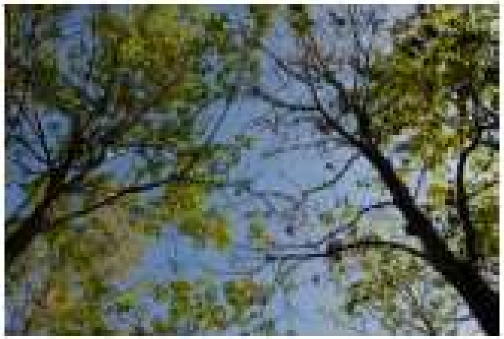
Why 57° towards North in the blue?

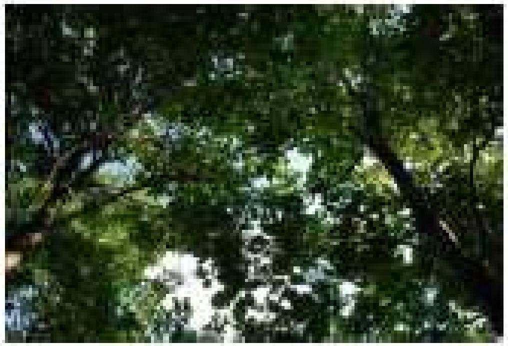
- Why blue spectral domain?
  - Better contrast between vegetation (almost black) and sky (rayleigh and aerosol scattering)
  - Limits multiple scattering in the canopy
- Interest of 57°
  - Minimization of leaf angle distribution effect
  - Minimization of plant clumping effect
  - Compromise between sensitivity (short path length) and spatial sampling (longer path length)
- Why North orientation?
  - Avoids direct sun light
  - Reverse to South in the southern hemisphere!

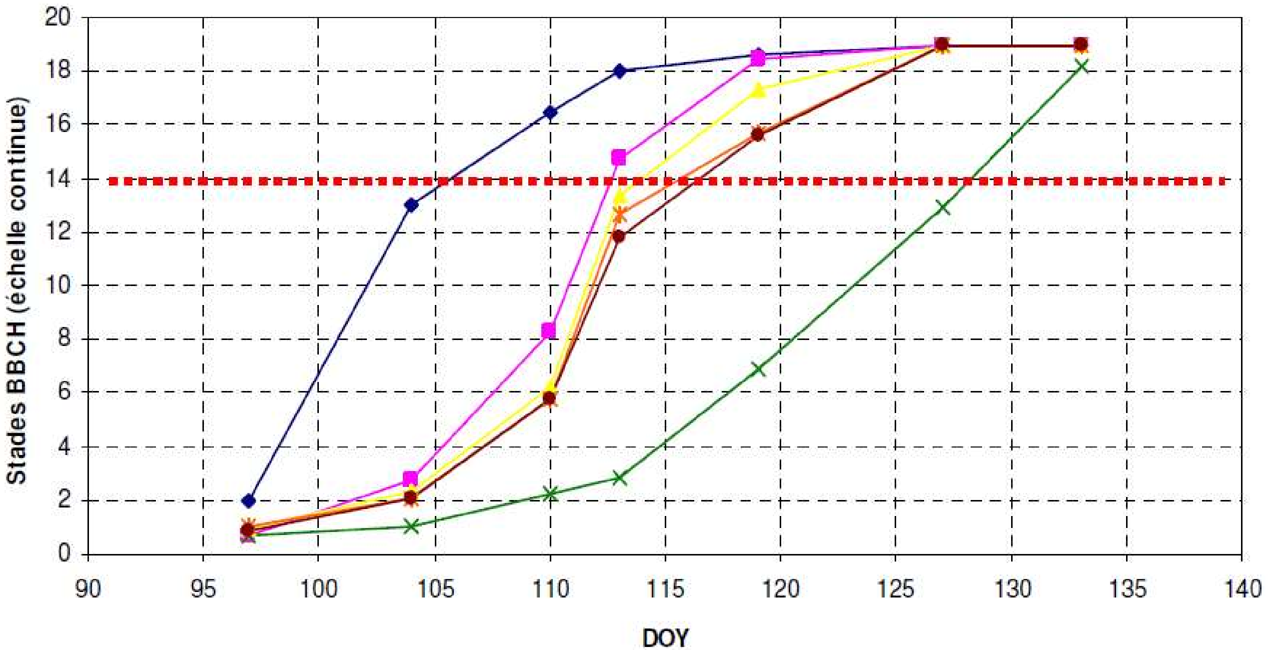
Some results on phenology: direct ground observations

14 April **7 May** **22 June**





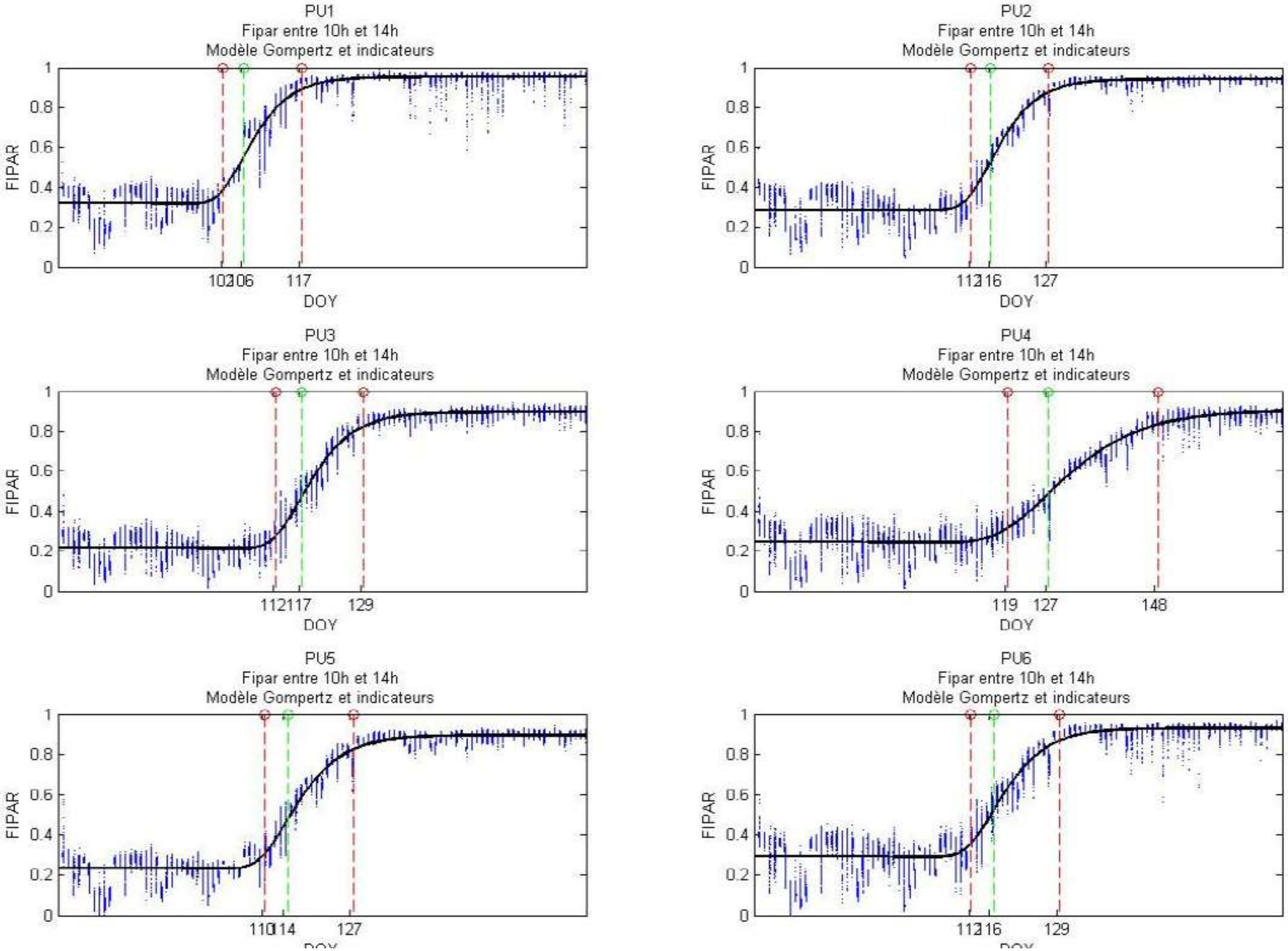




Typical dynamics measured

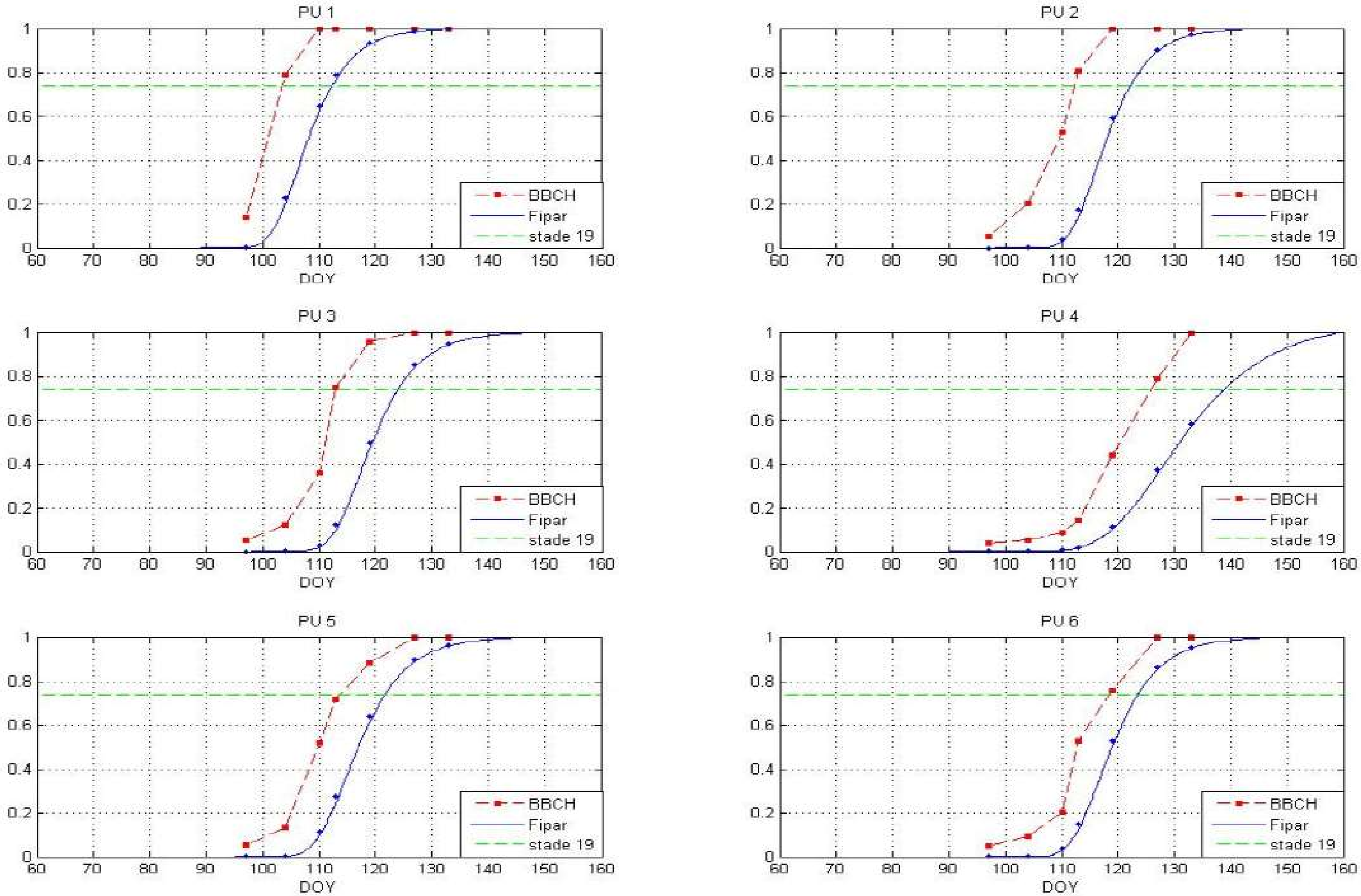
Incident

Transmitted

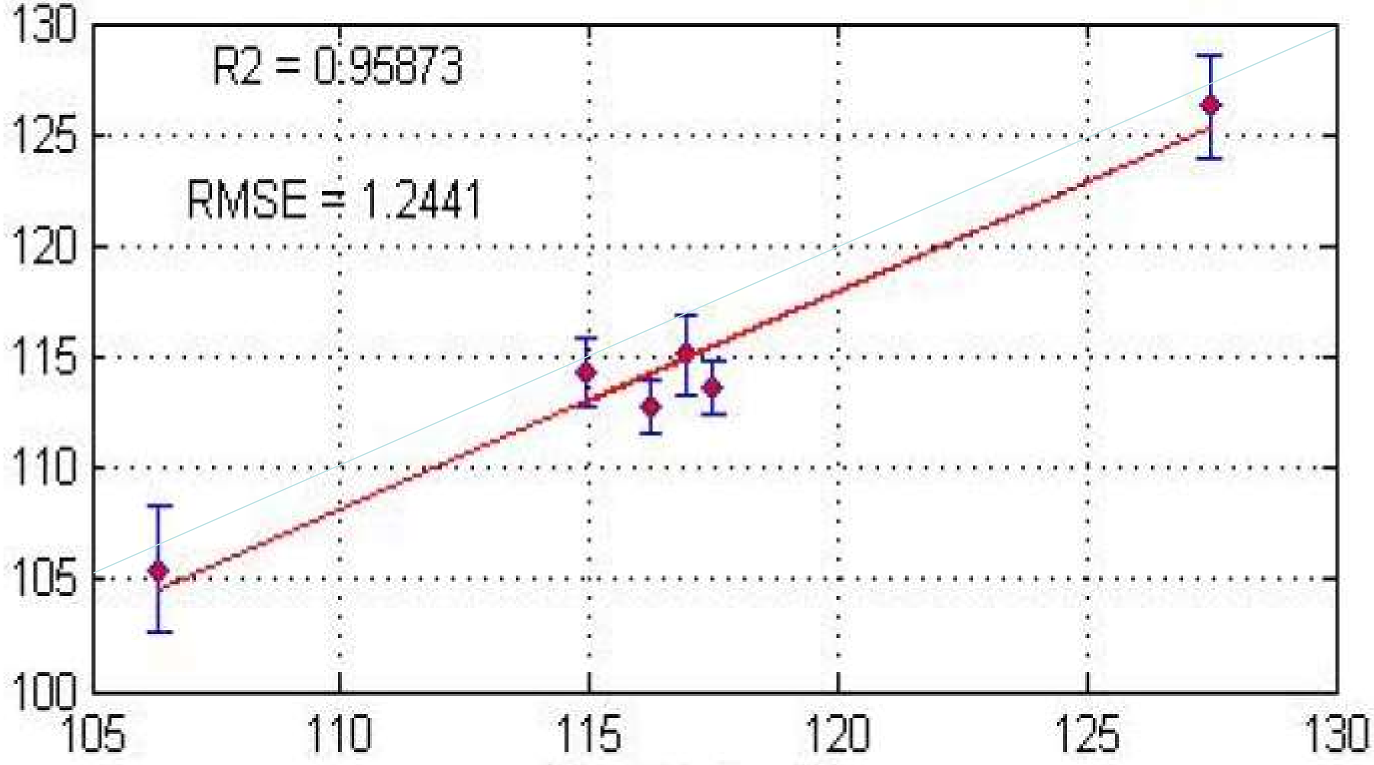


Prototype sensors (PAR domain, 40° zenith angle)

Comparison with visual notations

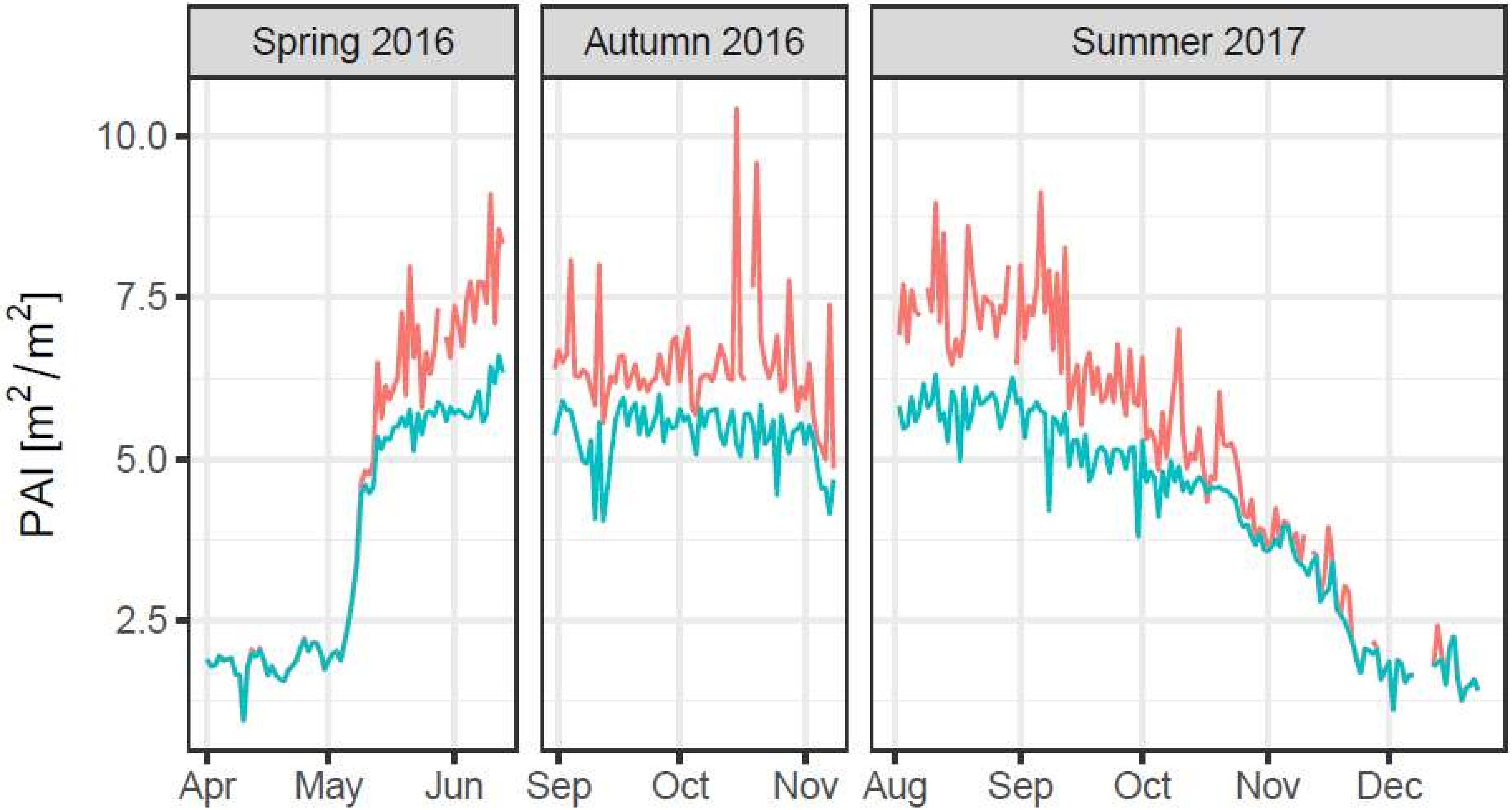


Performances of stages estimates

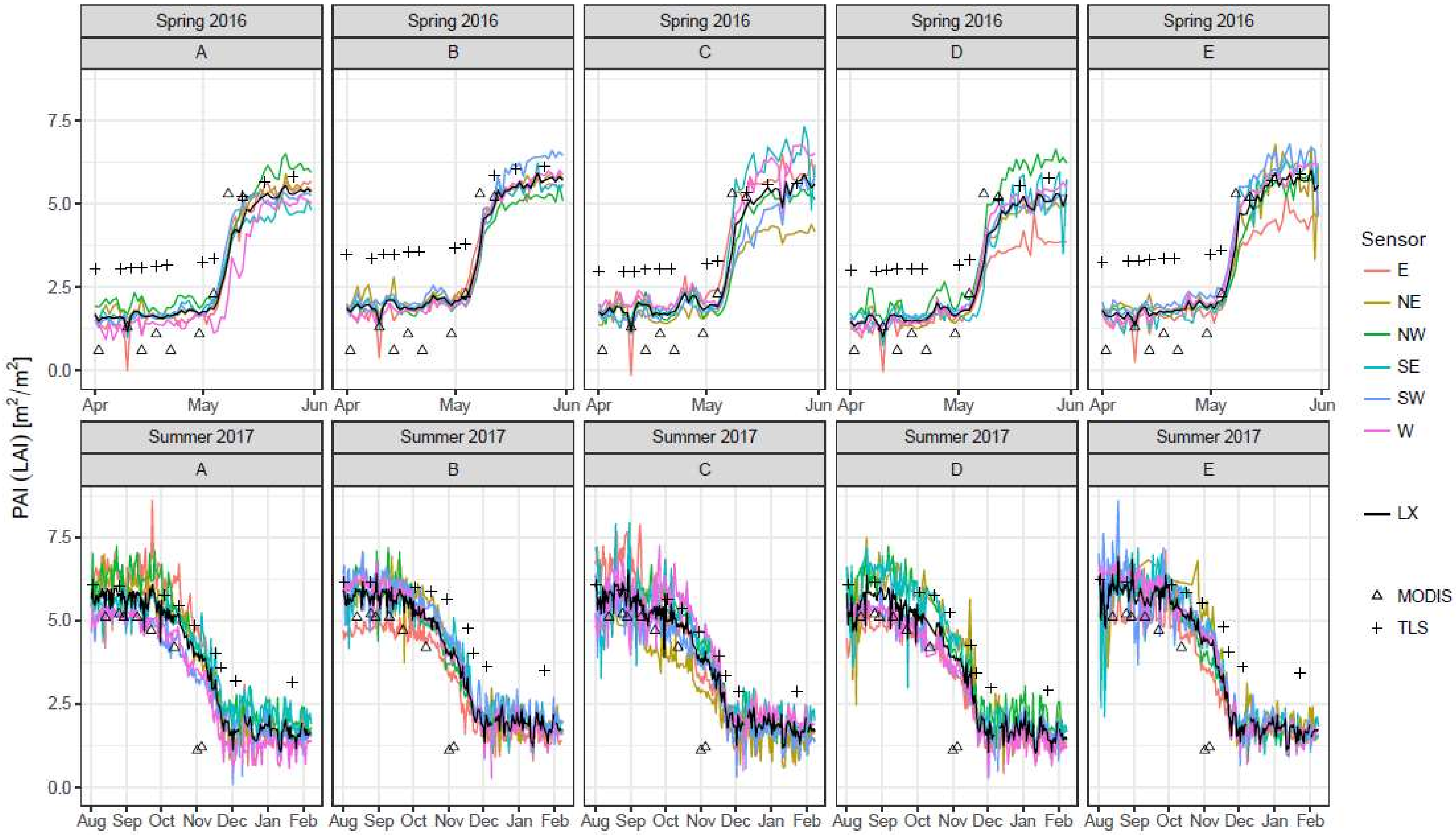


Date of inflection of BBCH Stage 19

Date of inflection from sensors



Spring 2016
Autumn 2016
Summer 2017
PAI [m2/m2]
10.0
7.5
5.0
2.5
Apr
May
Jun
Sep
Oct
Nov
Aug
Sep
Oct
Nov
Dec


Spring 2016
A
B
C
D
E
Summer 2017
7.5
5.0
2.5
0.0
Apr
May
Jun
Aug
Sep
Oct
Nov
Dec
Jan
Feb
PAI (LAI) [m2/m2]
Sensor
E
NE
NW
SE
SW
W
LX
MODIS
TLS

Conclusion

- (Relatively) low cost systems are now available for ground measurements of leaf development:
    - LAI
    - FAPAR
    - Albedo (PAR or PIR)
- Good performances with regards to visual estimates of phenology
- Good consistency with satellite observations