Sample results for LAI estimates from Hemisphotos and CAN_EYE

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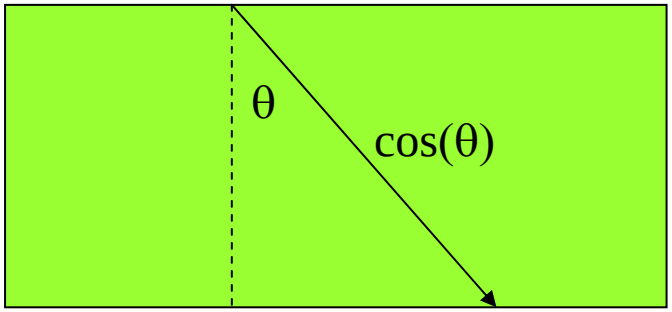
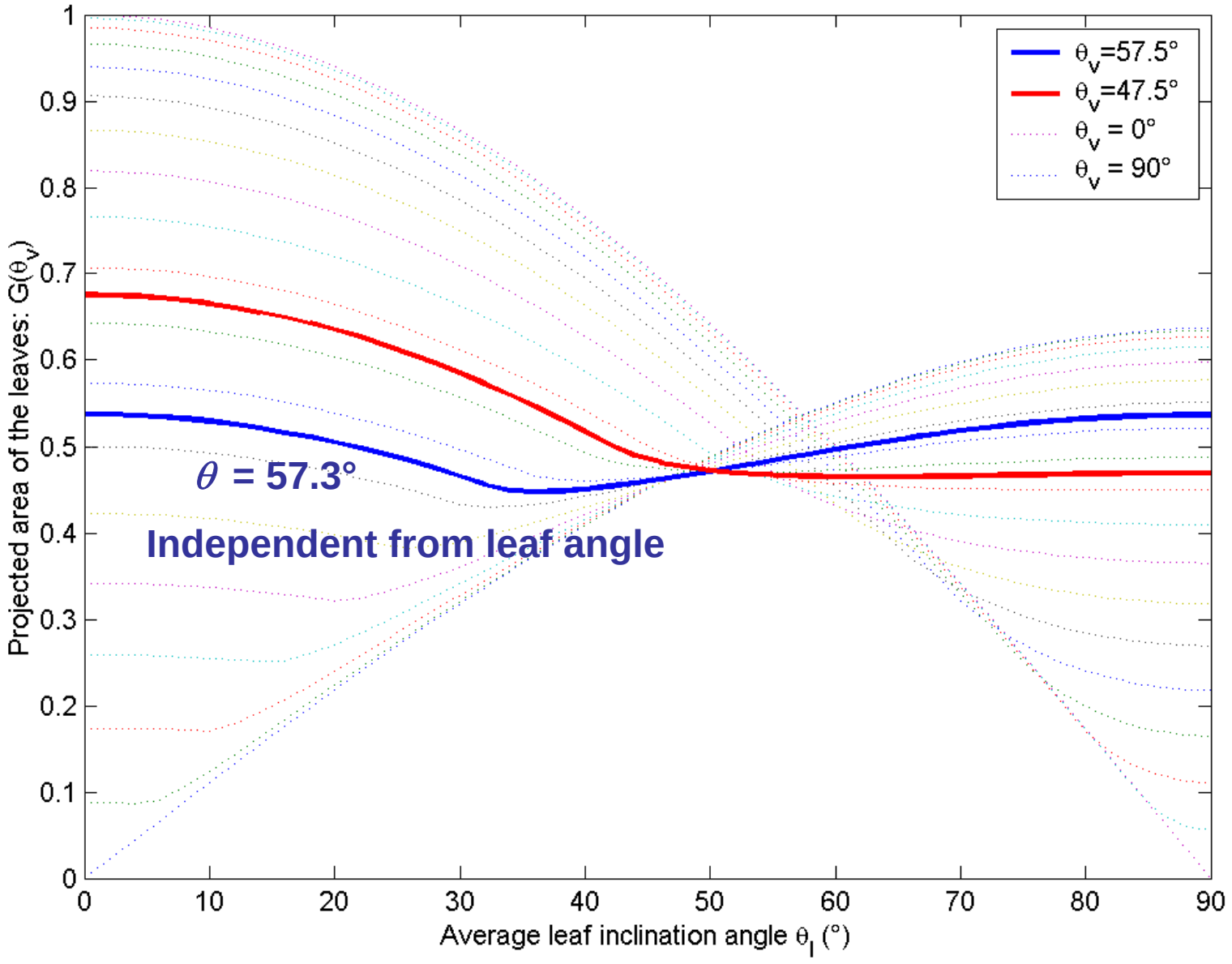
Basic principle

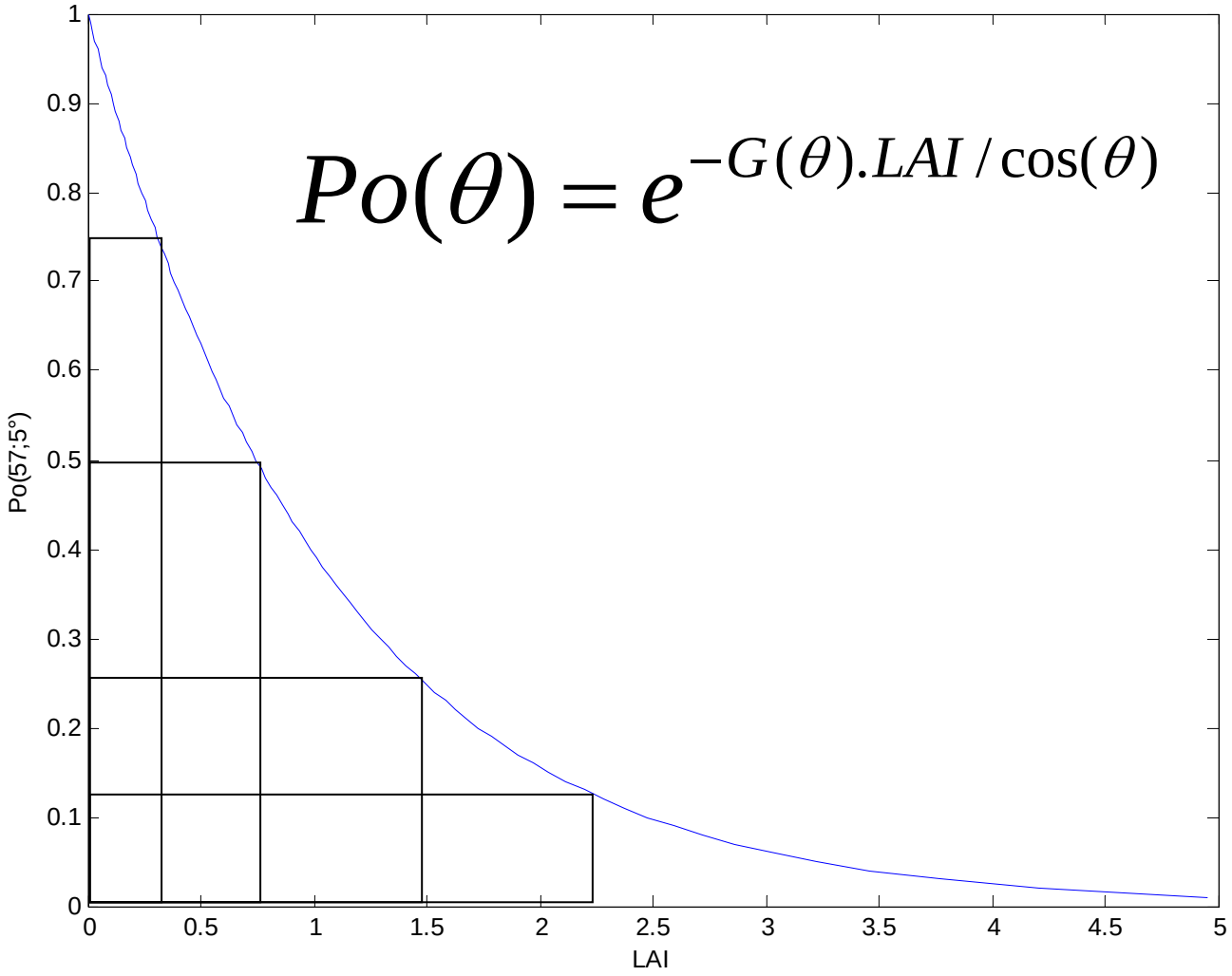
- fCover= $1\text{-}Po(0)$
- fAPAR(θ_s)≈fIPAR(θ_s)=$1\text{-}Po(\theta_s)$
- $$Po(\theta) = e^{-k.LAI} \qquad k = \frac{G(\theta, \theta_l)}{\cos(\theta)}$$



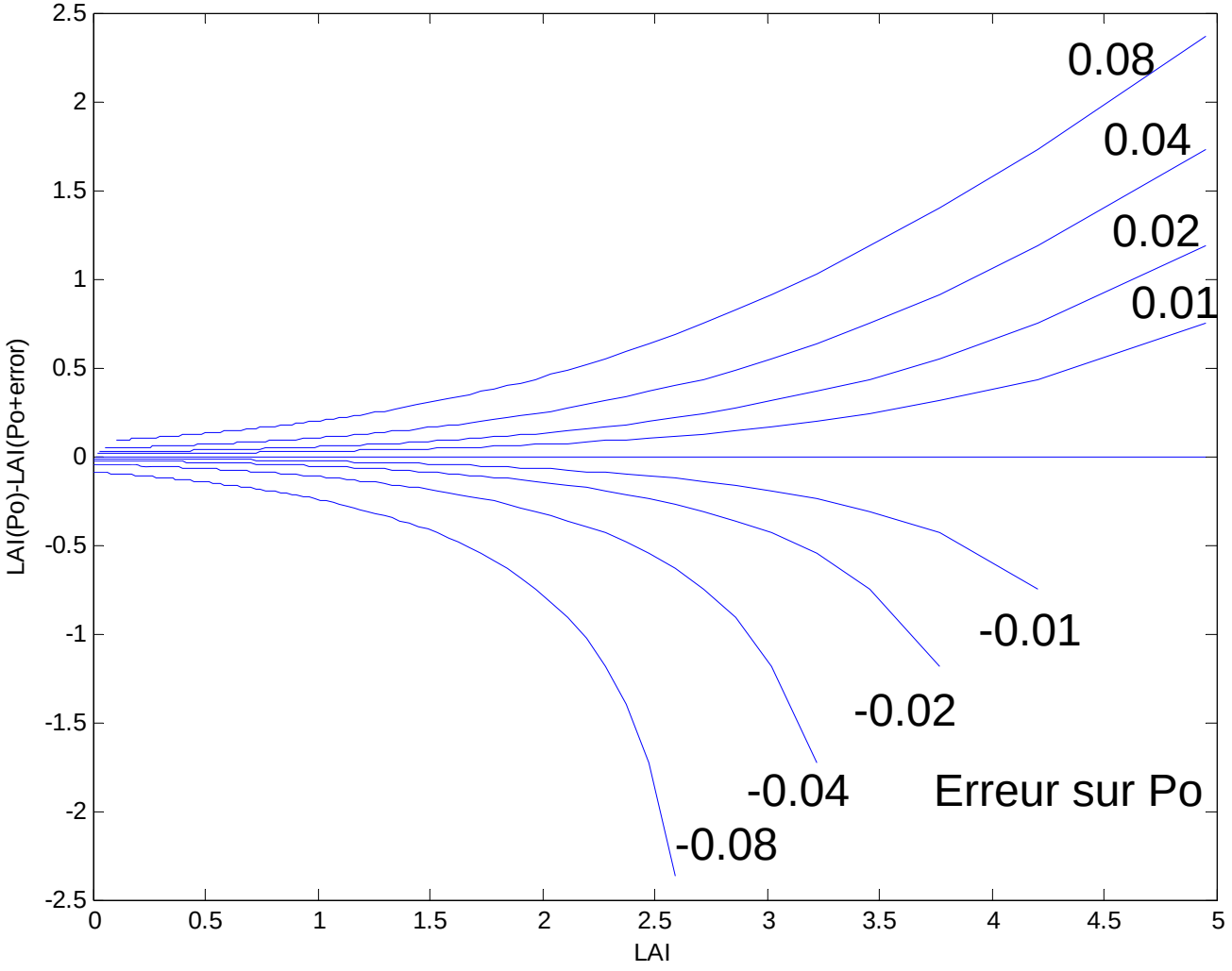
Projection function $G(\theta)$



Relationship between LAI and Po



Consequences on LAI estimates



Current measurement devices

Comparison between instruments allowing indirect LAI measurements

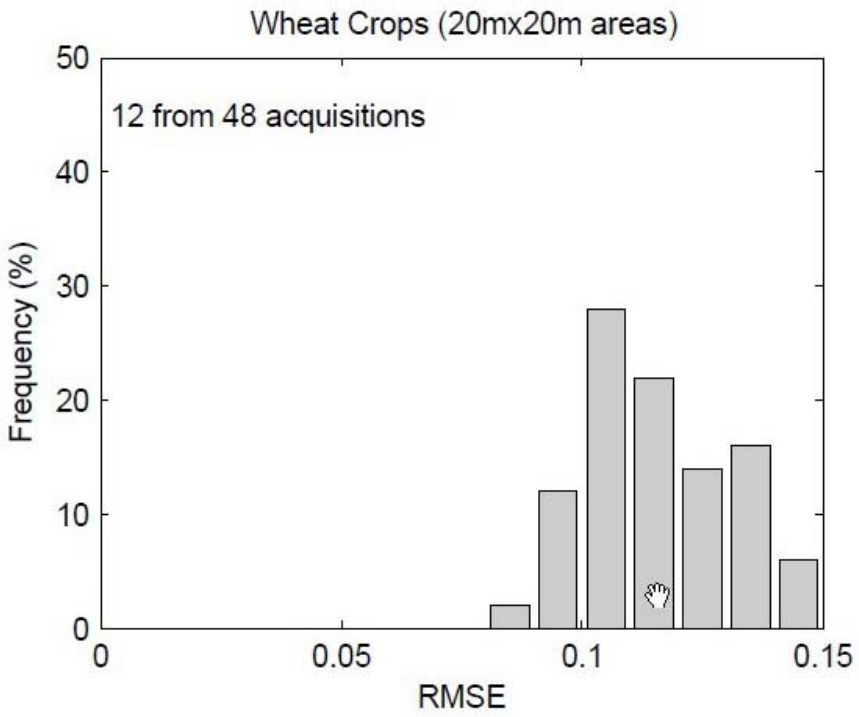
System	Illumination conditions	Spectral domain	No. of zenith angles	Azimuthal coverage	Gap size distribution	Reference readings	Post-processing	Computer resources
DEMON	Direct	430 nm	–	–	No	Yes	No	Low
Sunfleck ceptometer	Diffuse, direct	PAR	–	–	Yes	Yes	Yes	Low
AccuPAR	Diffuse, direct	PAR	–	–	Yes	Yes	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	–	–

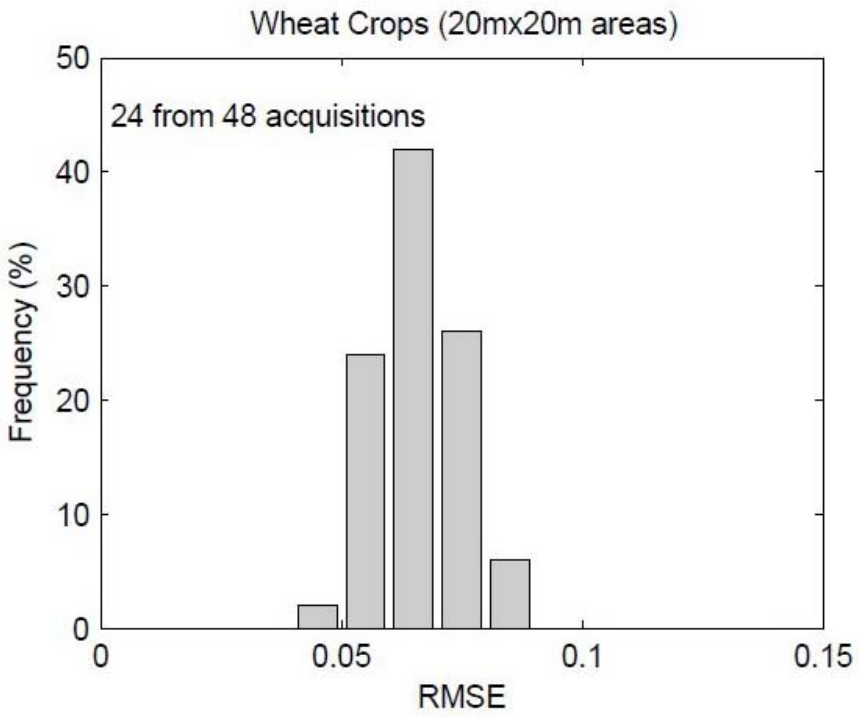
Interest of digital hemispherical photography (DHP)

- cheap (appareil+fish-eye<1000 euros)
- Easy to use (illumination conditions)
- No reference measurements
- Possible use over low vegetation canopies
- Directly evaluation of the quality of the measurements (images)
- Possible distinction between green and non green elements
- Possible to derive clumping information

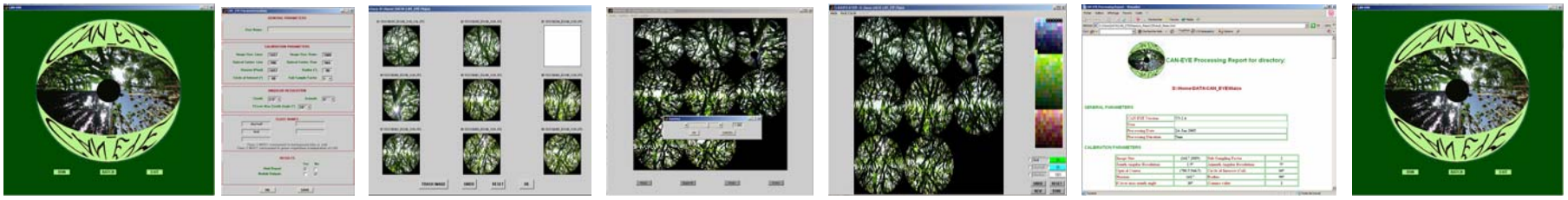
Spatial sampling

5 to 15 photos necessary for most canopies for 20x20m² ESUs





CAN_EYE: processing the images



Start → **Setup** → **Image selection** → **Pre processing** → **Classification** → **Processing & reporting** → End

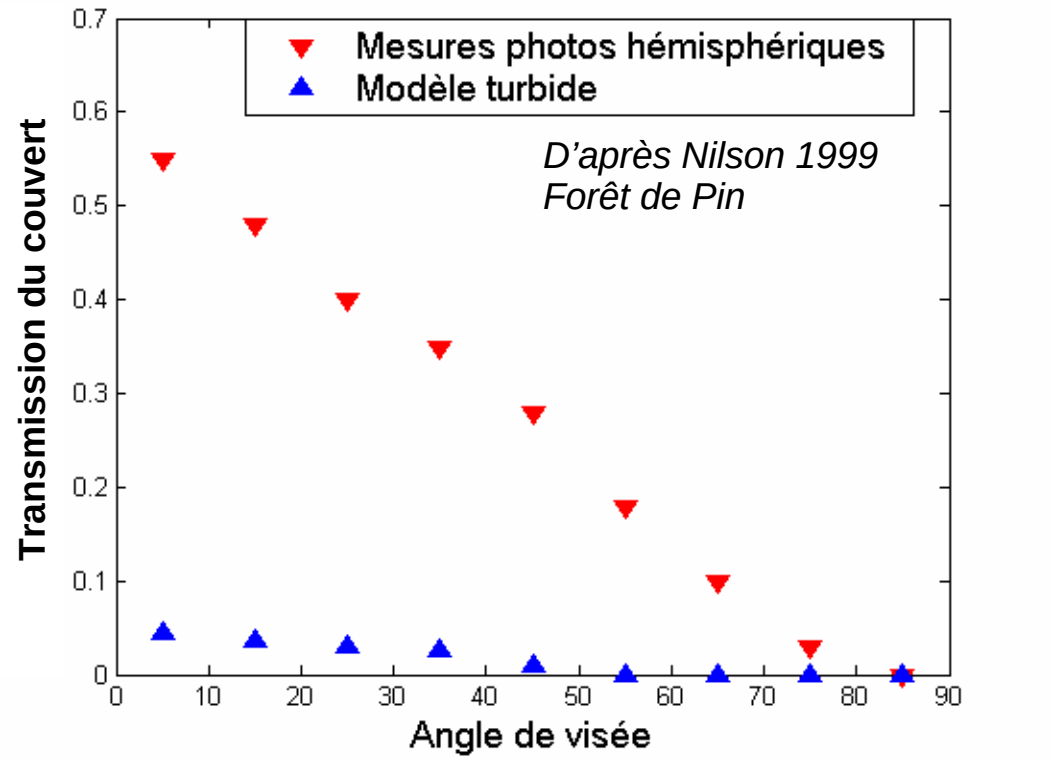
www.avignon.inra.fr/can_eye

The clumping problem

Homogeneous canopy

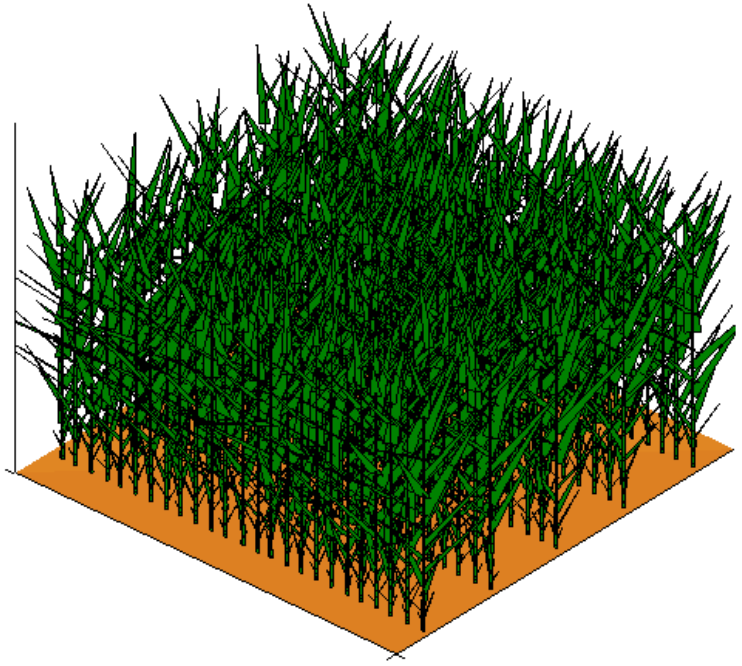
Clumped canopy

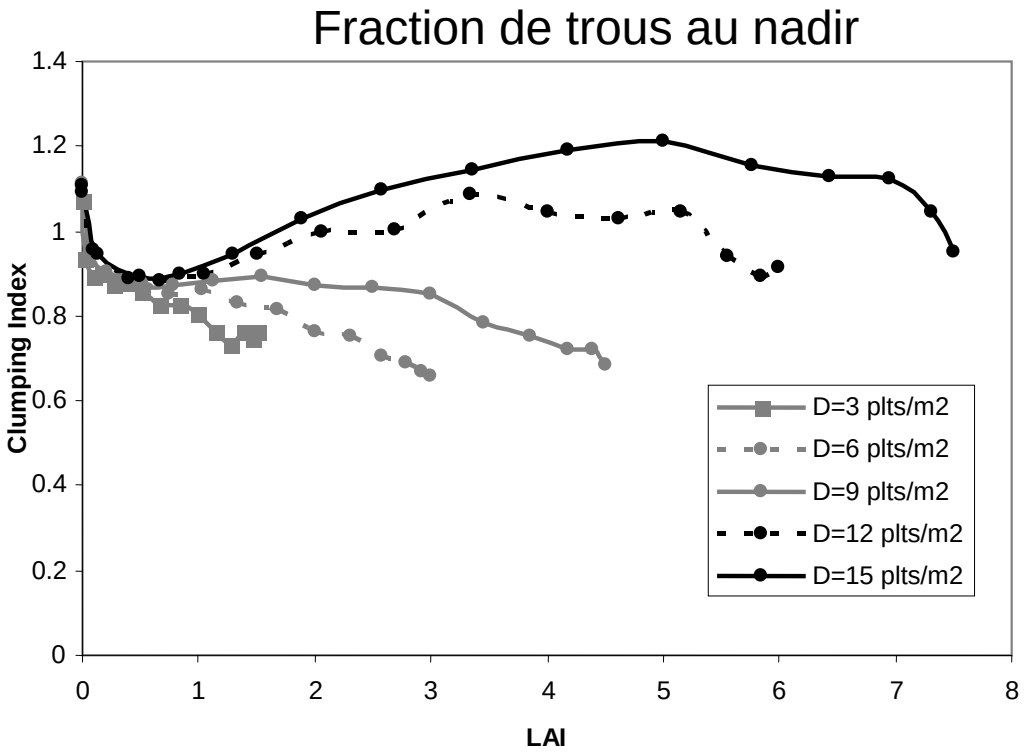
Effect of clumping on Po



Clumping has to be taken into account

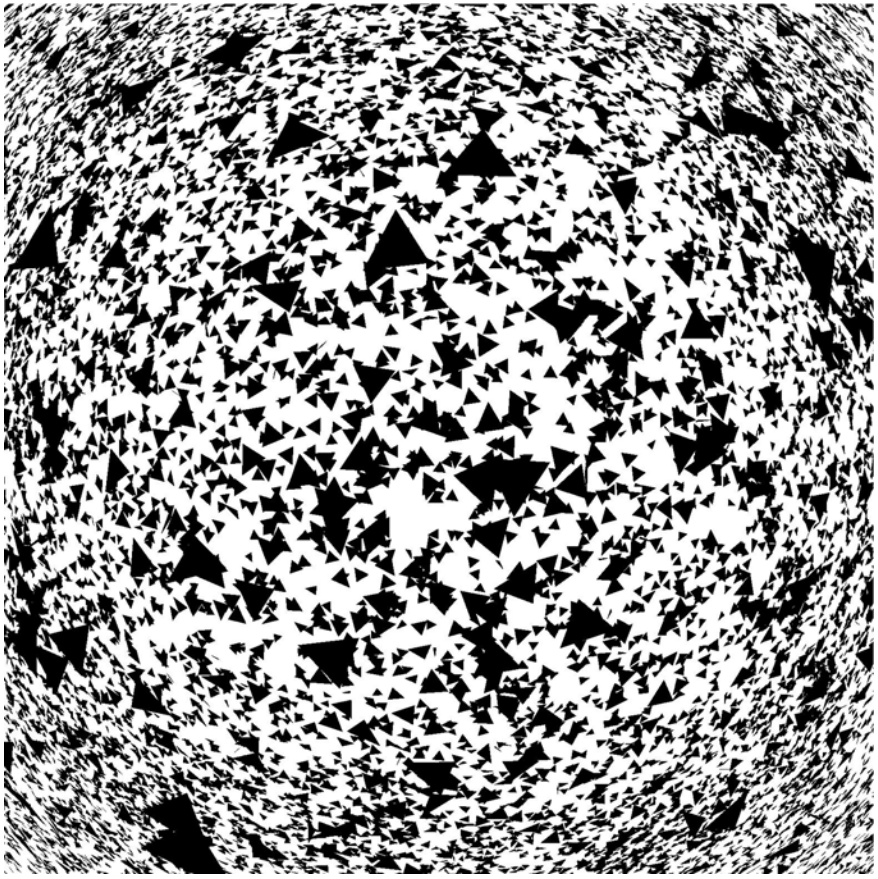
Exemple for simulated maize canopies





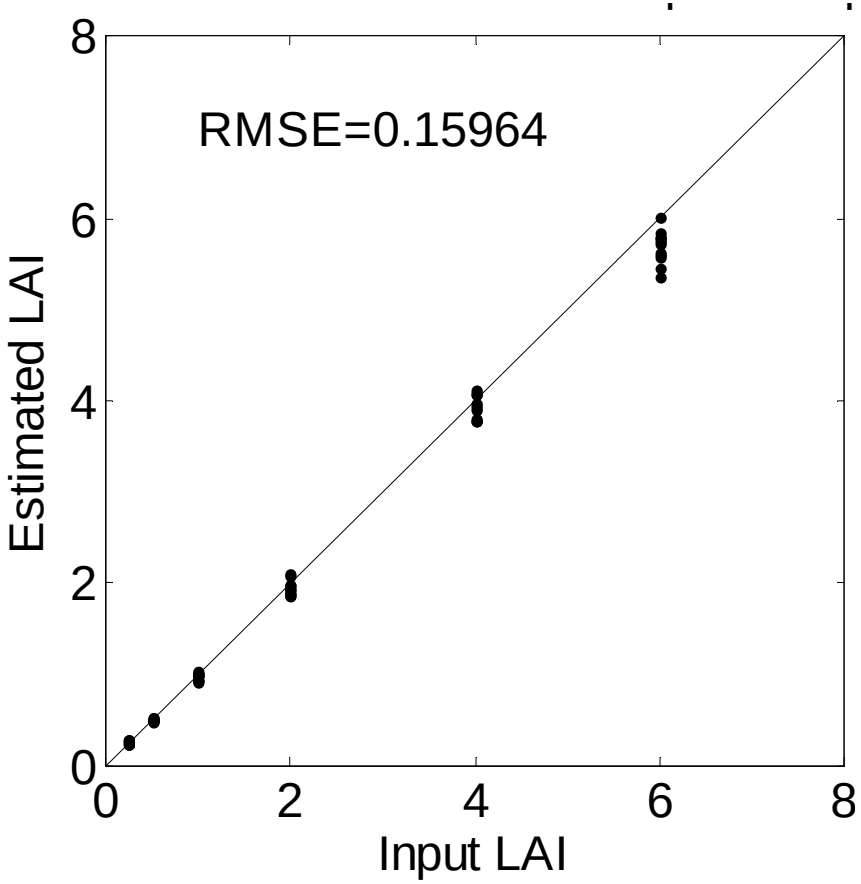
Validation of CAN_EYE: synthetic images

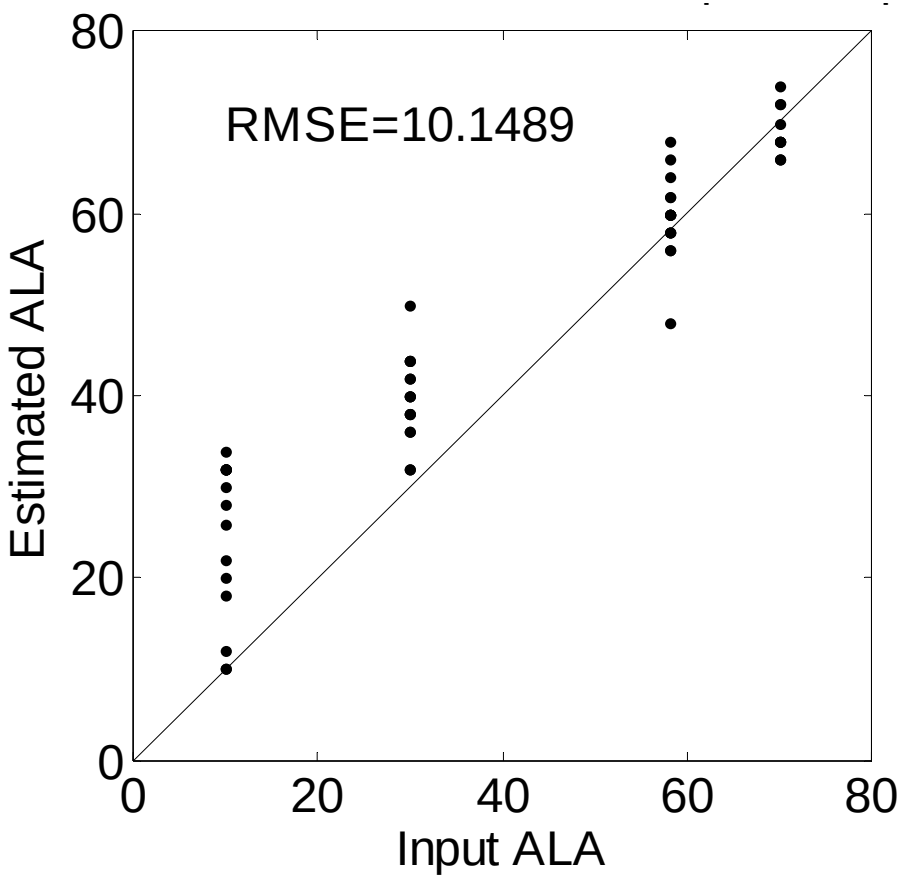
- Creating synthetic hemipsherical images of known cases (turbid medium)
- Processing with can_eye
- Comparing retrieved values with actual ones



CAN_EYE evaluation

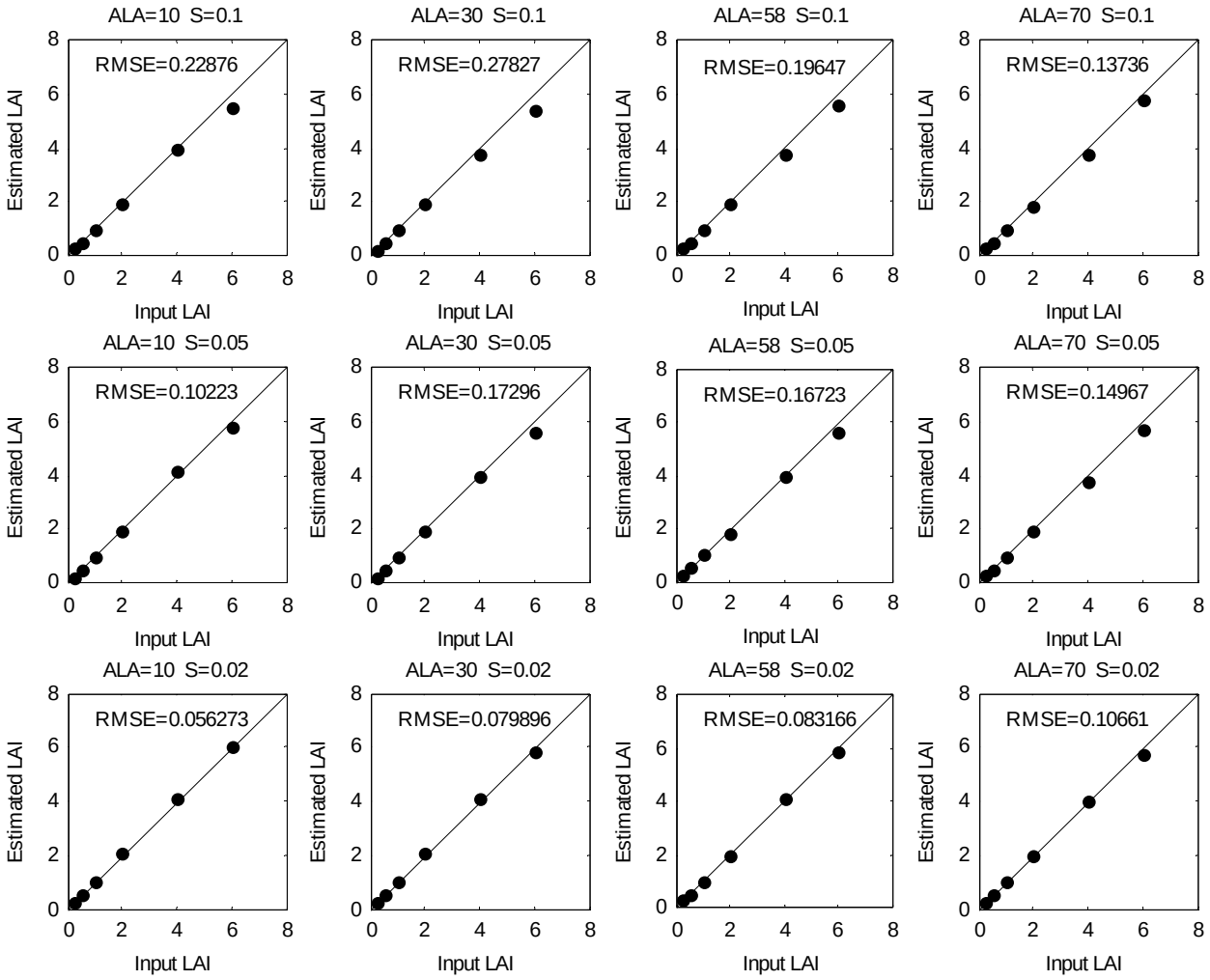
Effective LAI from hemispherical photos





CAN_EYE evaluation

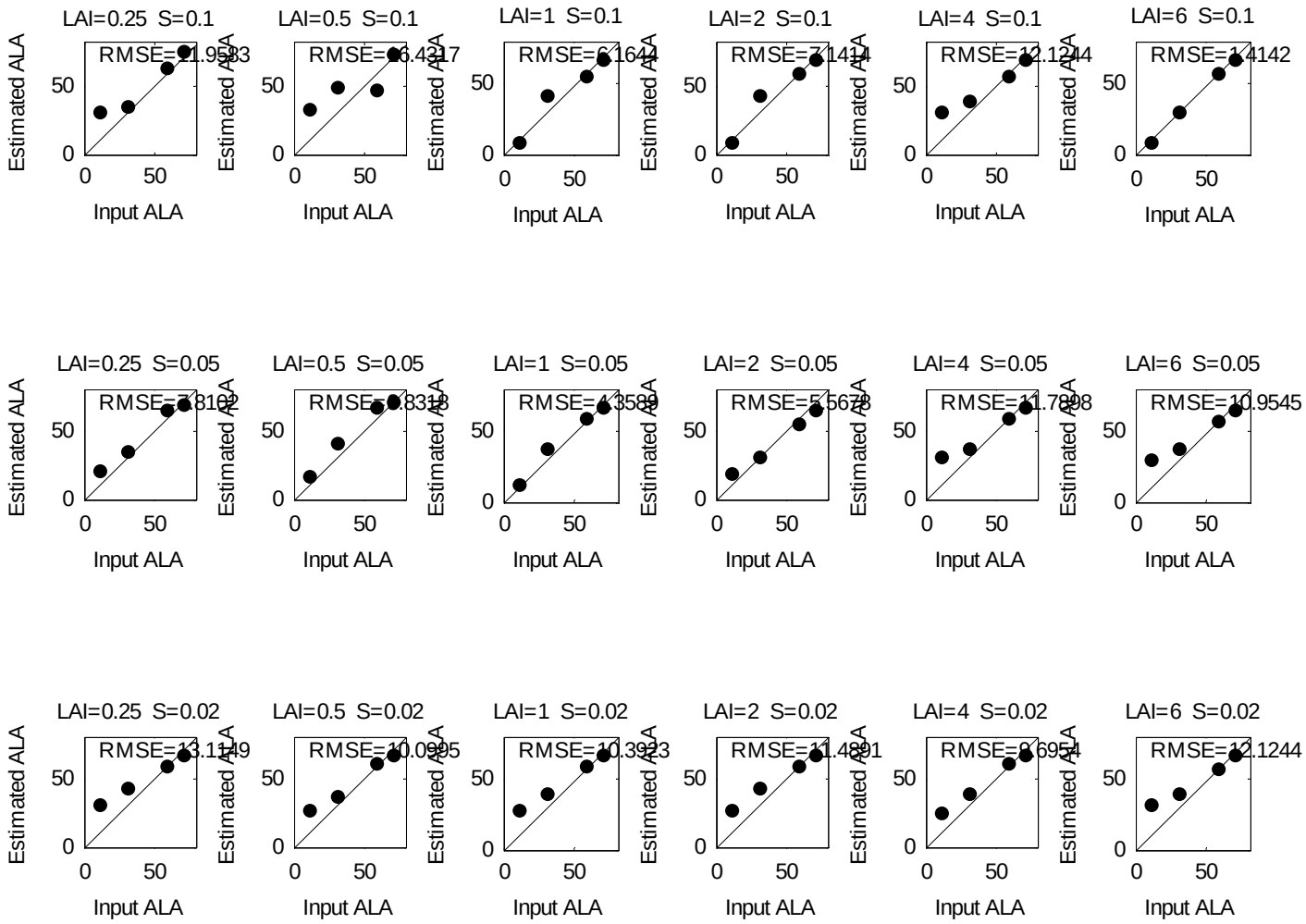
Effective LAI from hemispherical photos



Effect of the leaf size (clumping)

CAN_EYE evaluation

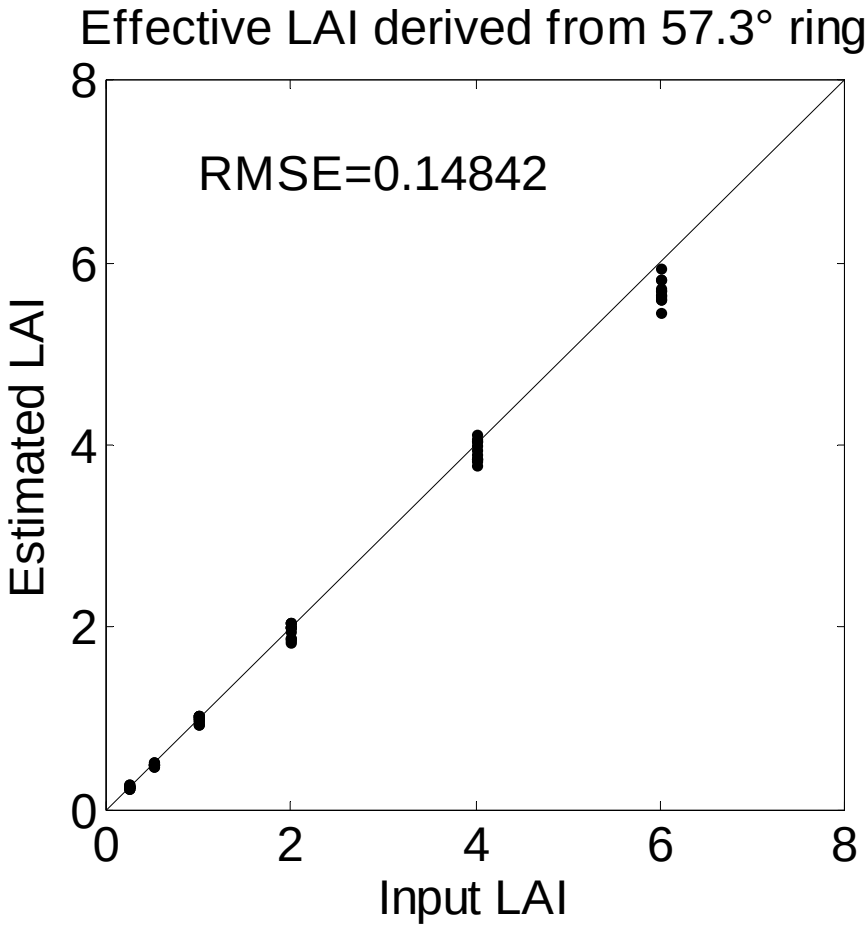
Effective LAI from hemispherical photos



Effect of the leaf size (clumping)

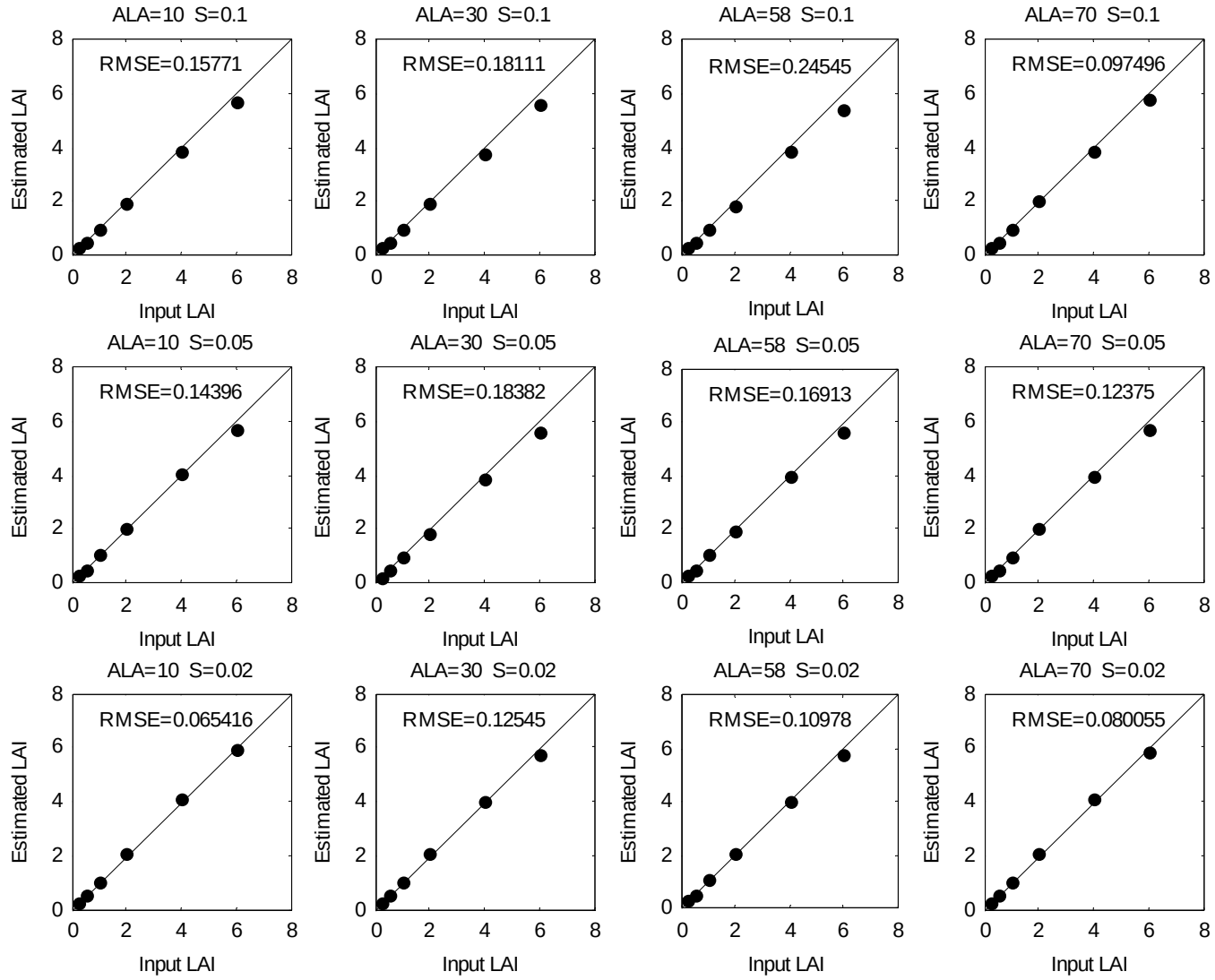
CAN_EYE evaluation

Effective LAI from the 58.3° ring



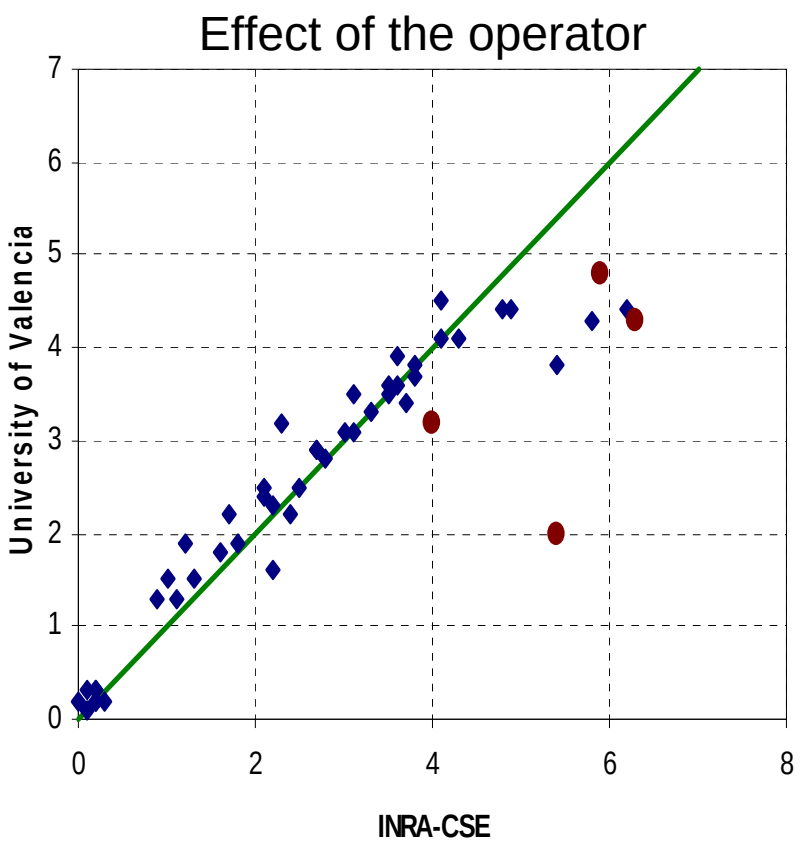
CAN_EYE evaluation

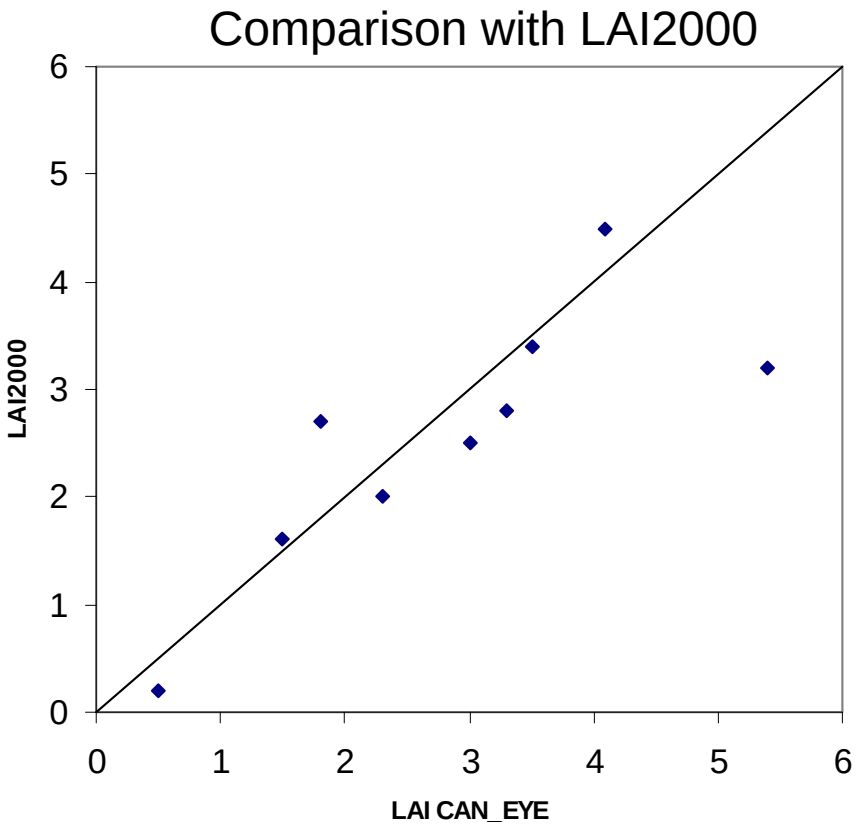
Effective LAI from hemispherical photos



Effect of the leaf size (clumping)

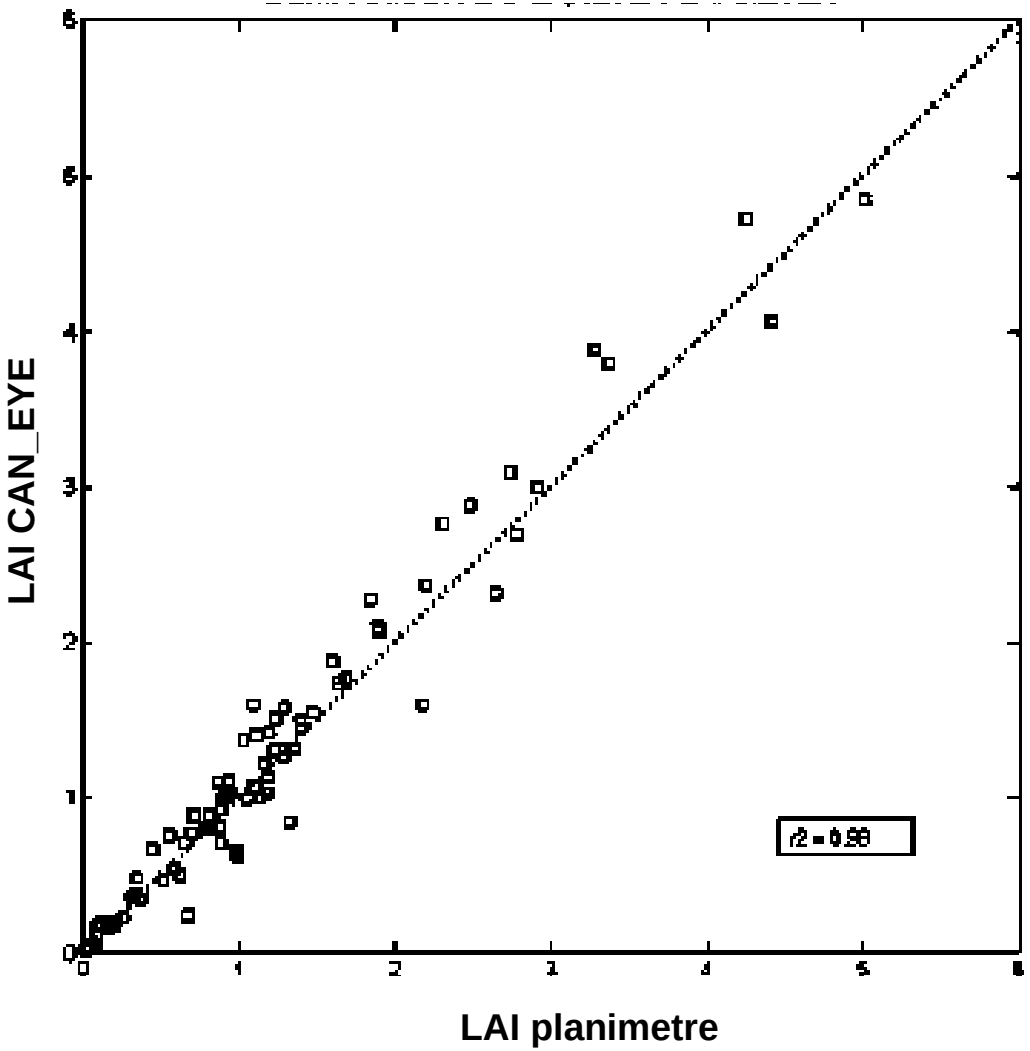
Results 1/4: Barrax

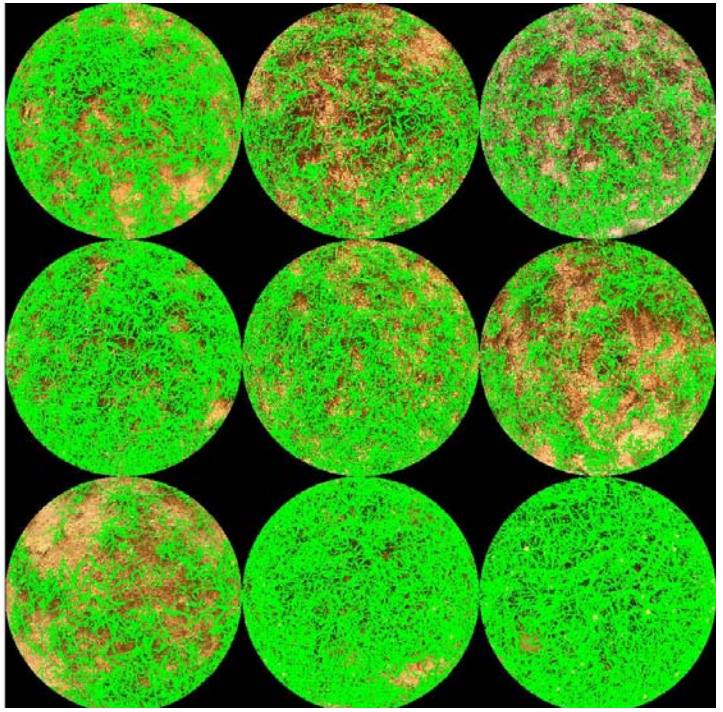




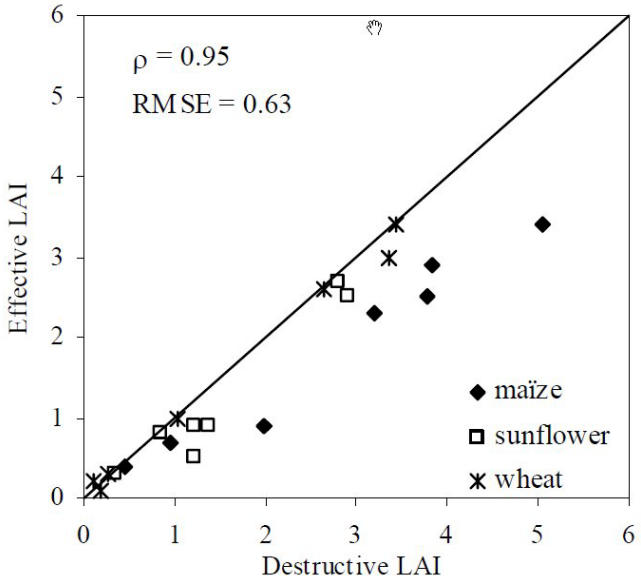
Results from the 2004 campaign

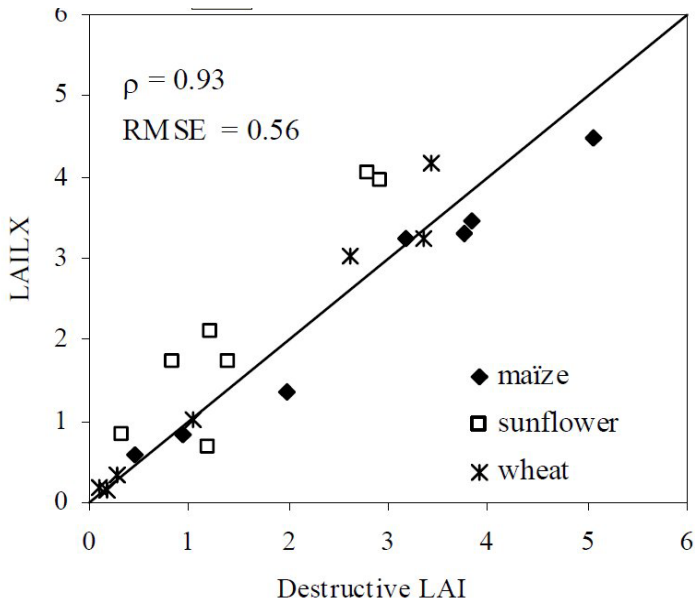
Results 2/4: Mali

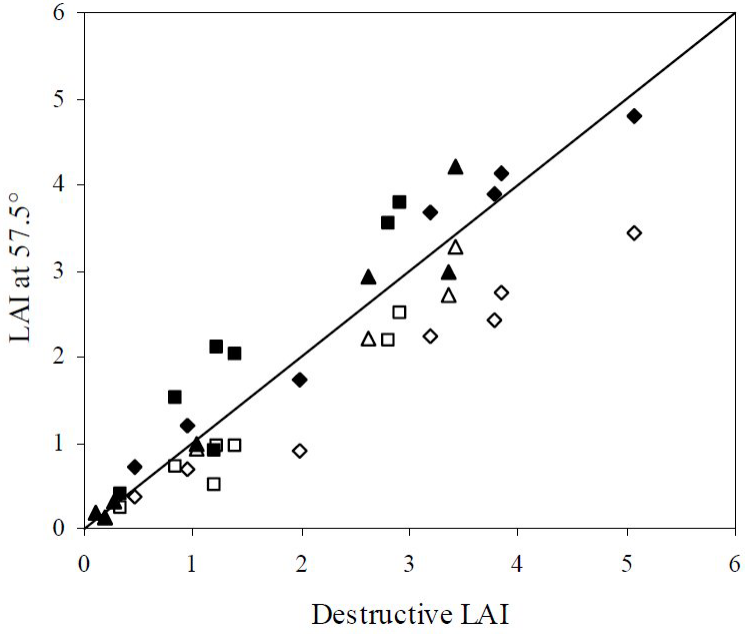




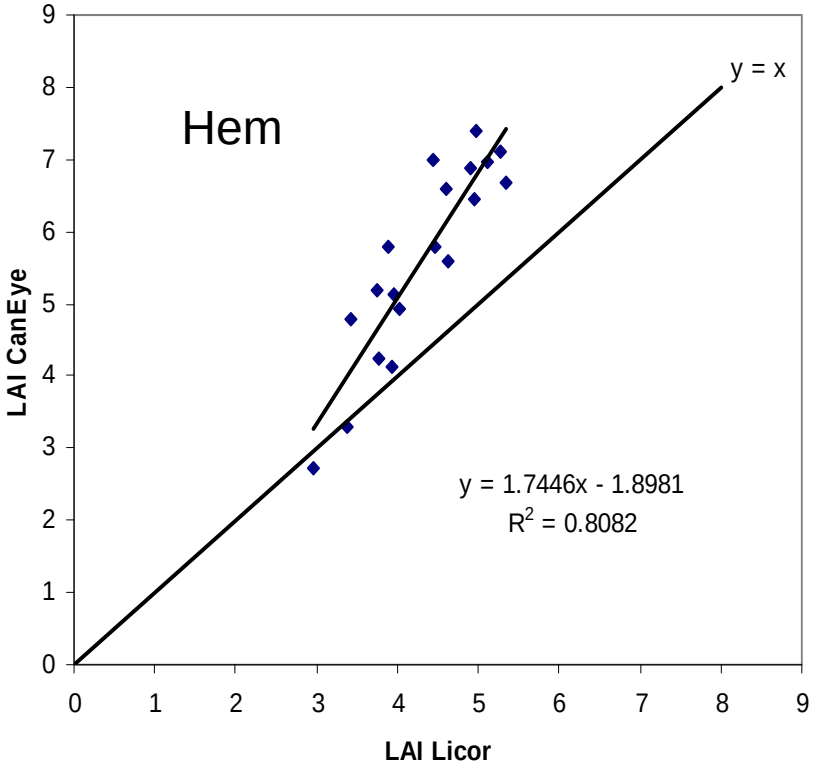
Results 3/4: Sud-ouest

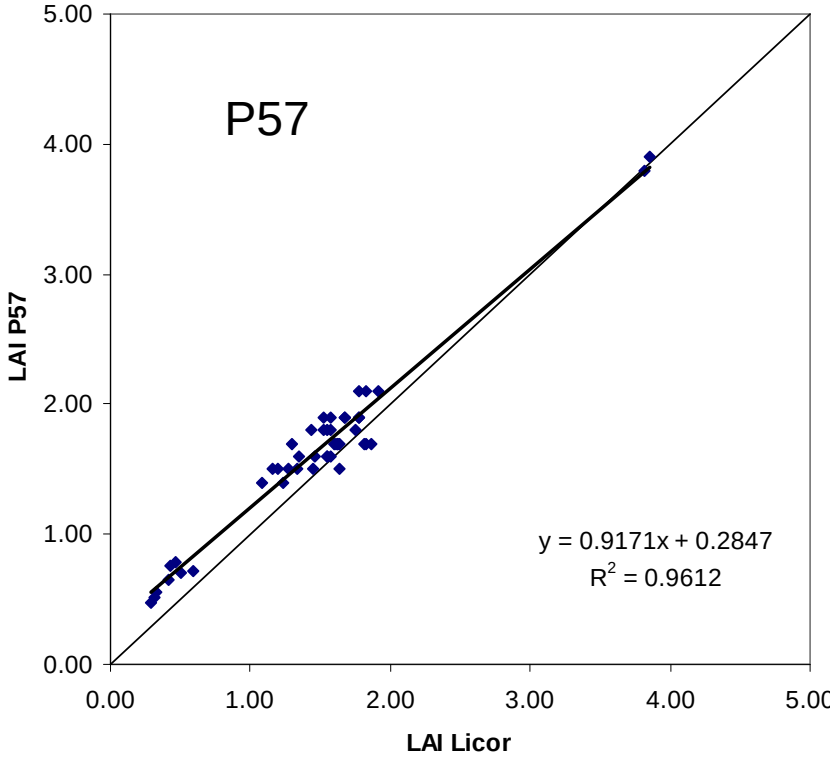






Resultats 4/4: ARVALIS






24.02.2004


Hemispheric

Conclusion

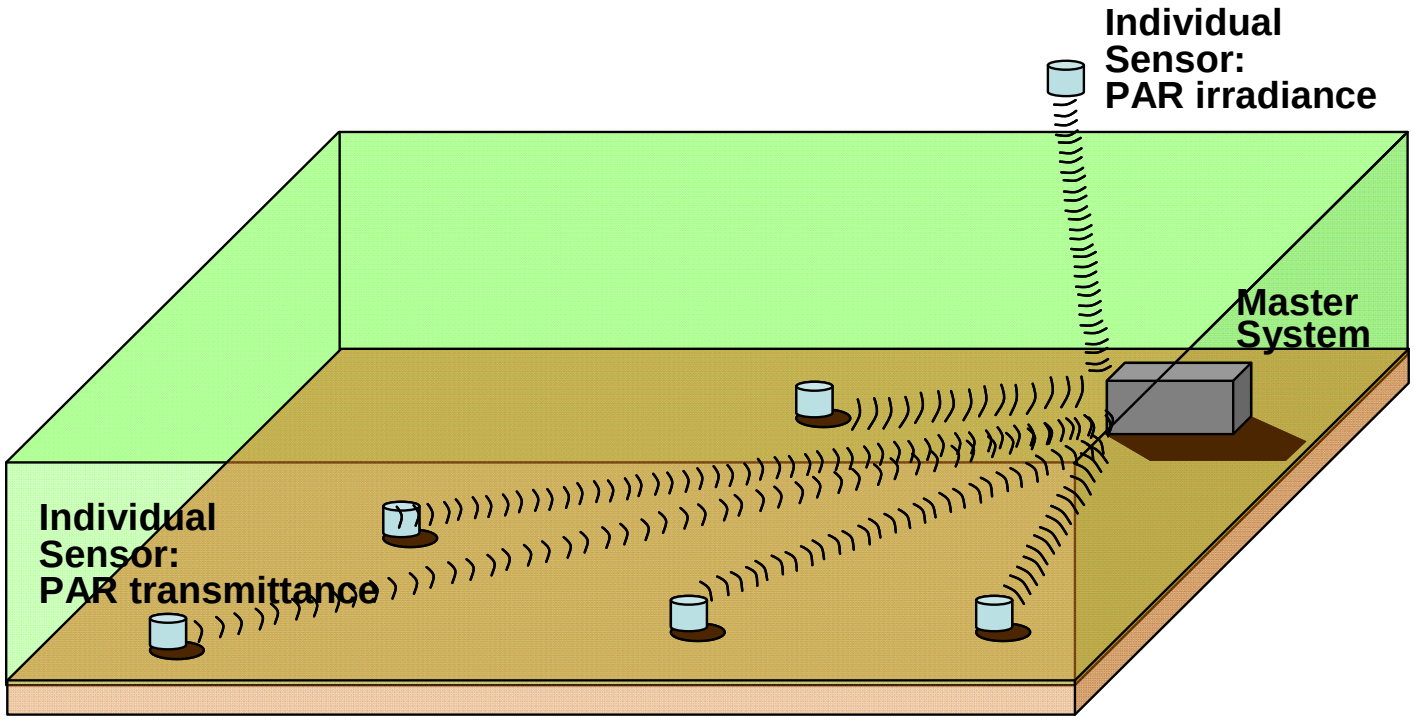
- For effective LAI good performances
- Results depend mainly on the quality of the photo:
  - illumination conditions (better diffuse)
  - Exposition (avoid saturation)
- Spatial sampling very important

- Need further developments for clumping (true LAI)
  - (ongoing activity)

PAR@METER

- Continuous monitoring of PAR balance
- No wires
- Large autonomy (6 months)
- Low cost
- LAI estimates from transmitted PAR

PAR@METER


Individual
Sensor:
PAR irradiance
Master
System
Individual
Sensor:
PAR transmittance

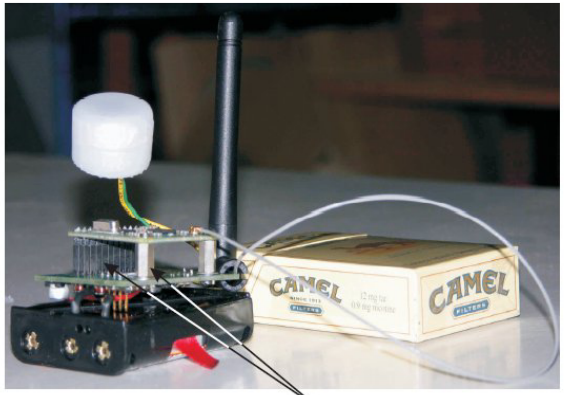
Par@METER (3/4)

Afficheur LCD
2 lignes de
40 caractères

"Clavier" (pour démo)
le clavier définitif sera
simplifié (8 touches) et
sera une membrane
intégrée dans la sérigraphie
de la façade

Antenne
(emplacement
à définir avec
design du
coffret)

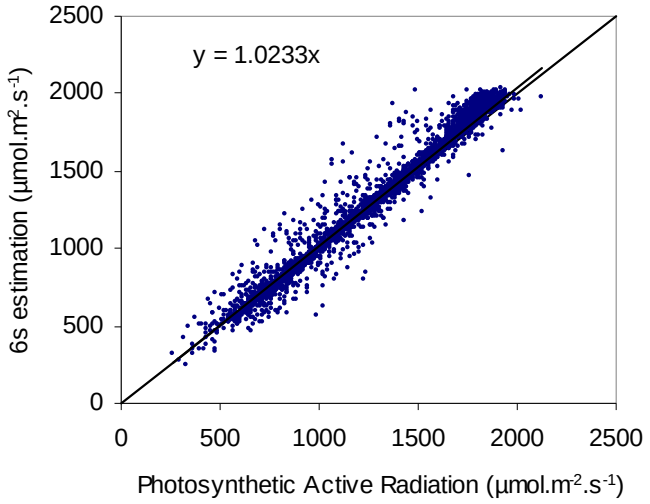
Module W.USB



Colonettes et connecteur de fixation
du module WUSB
Dans la version industrielle, le module WUSB
sera soudé directement sur la carte de traitement
(espacement 2 à 3 mm au lieu de 11 mm actuellement)

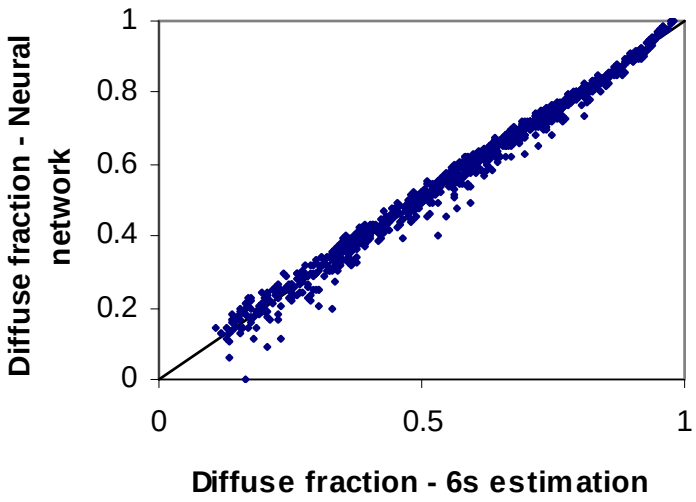
Hemispherical incident PAR

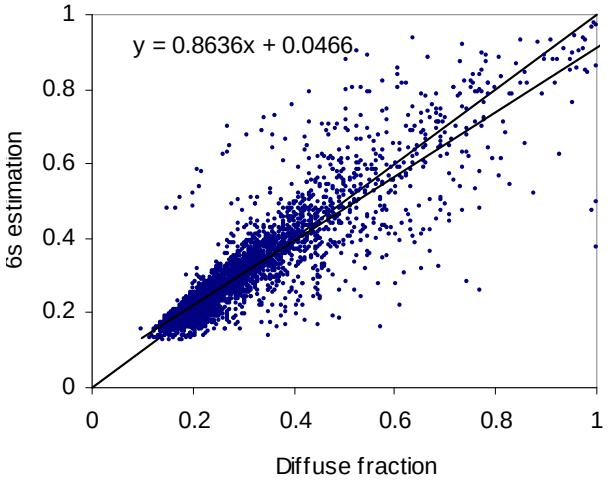
Calibration with 6S model simulations and AERONET atmospheric characteristics (θ_s<60°)



Incident PAR diffuse fraction

Derivation from exo-atmospheric radiation and semi-empirical model calibrated with 6S



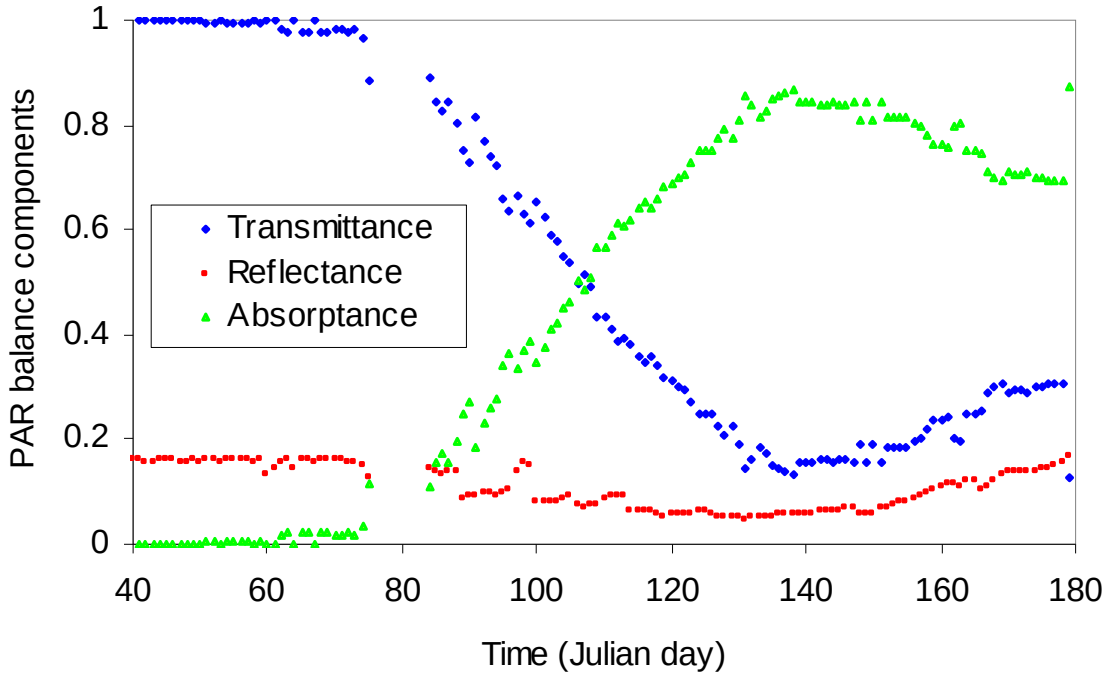


PAR balance measurements

In PAR domain, fPAR is approximated by:

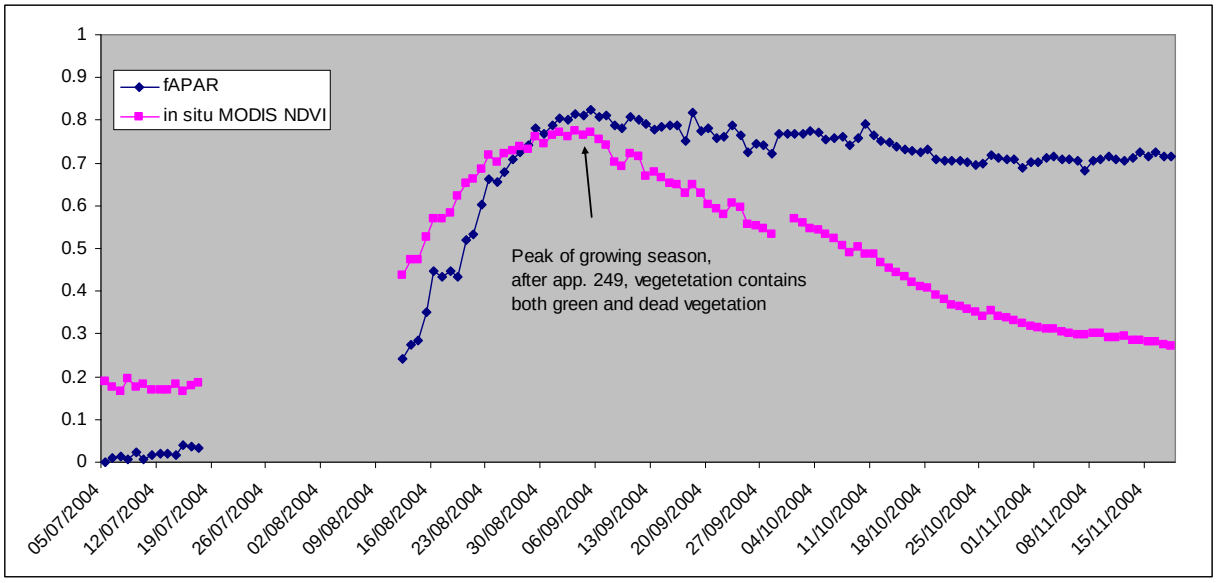
$$fPAR \approx 1 - Transmittance$$

Continuous monitoring over wheat crops
Possible problem: no distinction between green and non green elements



Example over maize canopies Avignon 2001

Possible problem: senescent vegetation



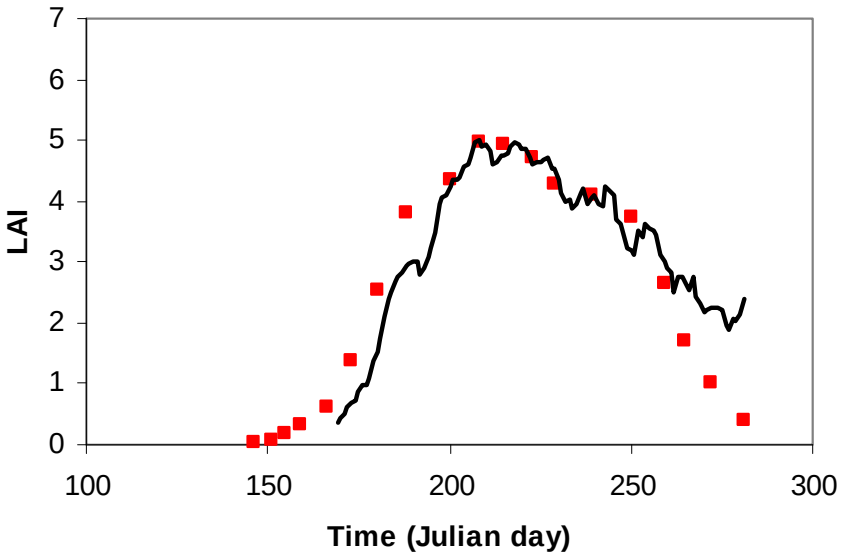
Presence of senescent vegetation intercepting radiation

Dahra 2004 data from Rasmus fensholt

LAI estimates

LAI is derived from the gap transmission measurements accumulated over few days. This provides variation of sun position and diffuse fraction.
Poisson model is inverted over these measurements allowing to derive both LAI (effective) and leaf inclination (effective) according to:

$$Po(\theta) = e^{-G(\theta).LAI/\cos(\theta)}$$



Example over maize canopies
Avignon 2001

Example over maize canopies

Conclusion

- Sytem under laboratory tests (communication, software…)
- Soon available
- Low cost
  - Sensor ≈ 100 Euros
  - Master ≈ 700 Euros

1 ESU ≈ 1.7 kEuros

- Allows monitoring the seasonality
- Soon equipping permanently few sites