Centre d'Etudes Spatiales de la BIOsphère
Unité Mixte de Recherche(CNRS,UPS,CNES,IRD)

LPVE workshop 2014
28-30 January

Cartography of irrigated crops and estimation of biophysical variables with high temporal and spatial resolution images

Perspective of Sentinel-2 mission

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Introduction and objectives

Sentinel-2 mission will combine high spatial and temporal resolution (HSTR)
→ new perspectives for cartography and crop modeling

MAISEO project :

→ **Help water managers to estimate and anticipate water needs in order to optimize water supplies at large scale (watershed)**

CALVADOVS project :

→ **Evaluation of validity and robustness of methods for estimation of biophysical variables with HSTR images**
= Operationnal context

Introduction and objectives

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→ new perspectives for cartography and crop modeling

MAISEO and CALVADOVS projects

Crops management and monitoring

- Water needs and supplies on irrigated crops
- Crops yield

Biomass, Yield

ETR and water supplies

↑

Robusts and operationnal methods

Introduction and objectives

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MAISEO and CALVADOVS projects

Crops management and monitoring

- Water needs and supplies on irrigated crops
- Crops yield

Biomass, Yield
ETR and water supplies

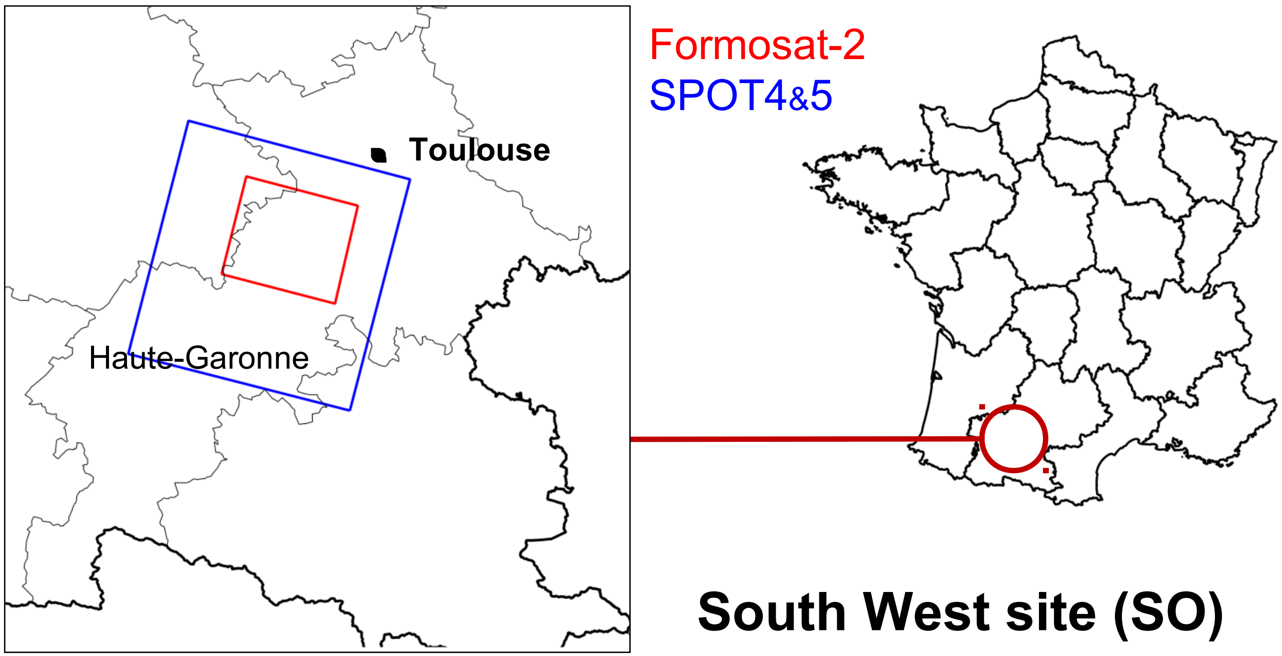
Robusts and operationnal methods

Part 1 — **Detection of summer crops and irrigated surfaces**
→ at the beginning or throughout irrigation period

Part 2 — **Estimation of biophysical variables**
- produce maps and profile of GAI(1), fAPAR, Fcover
- simulation of BIOMASS and YIELD

(1) Green Area Index, similar to LAI

Part 1 : Cartography – Dataset and study area



South West site (SO)

<u>Satellite data 2009 :</u>
15 images Formosat-2 and **6** images SPOT4&5 - From march to october

<u>Field data</u> : RPG = annual land cover for crops
→ Agriculture GIS used for the Common Agricultural Policy
Available long time after crops period

Part 1 : Cartography - Summer crops

1 - Early detection of summer crops

- Extract total crops previous year → Crop mask
- Multidate thresholding with NDVI → summer crops extraction
  3 Formosat-2 images used (may and june)

Crop mask

Multidate thresholding

Summer crops extraction (red)

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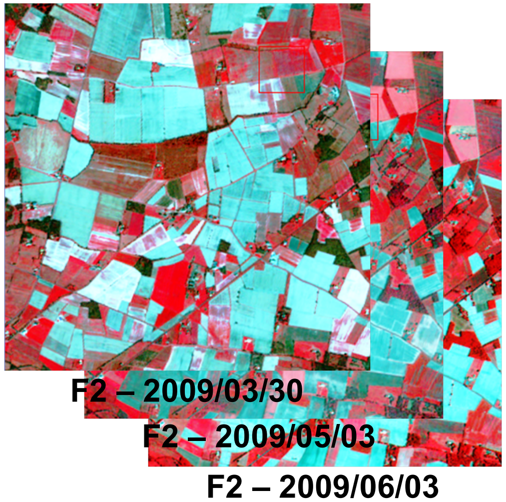
Crop mask



Multidate thresholding

Summer crops extraction (red)

Validation made with RPG 2009
98.32% from ~15.000ha well extracted

→ Summer crops extraction is effective from june

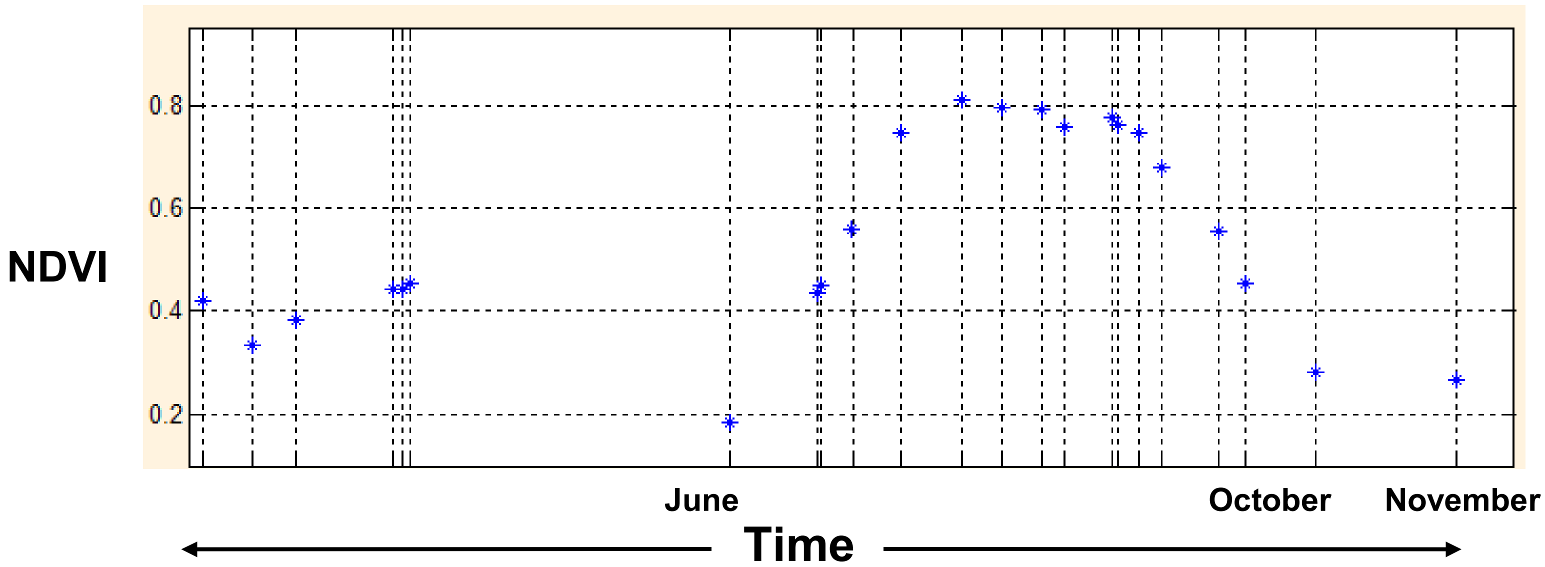
Part 1 : Cartography - Irrigated surfaces

1 - Early detection of summer crops

2 - Discrimination of irrigated areas

→ Summer crops phenological indicators

NDVI time serie on maize field



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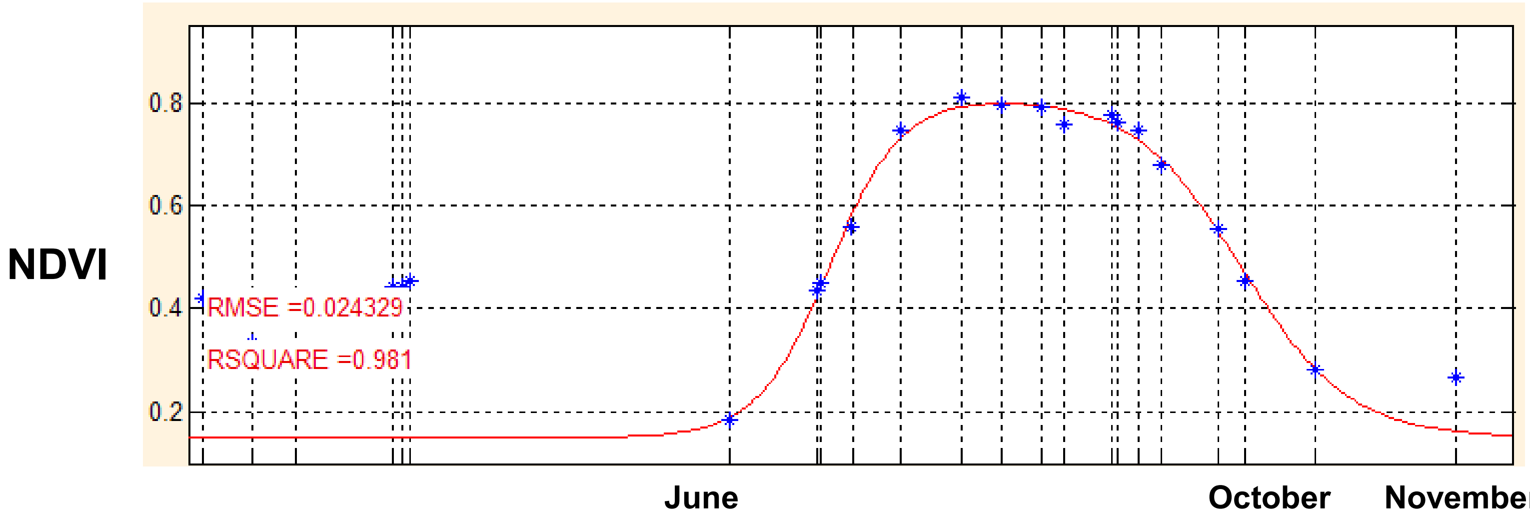


Interpolation by the double sigmoid (1)

→ **NDVI Tool :** interfaced program for automated extraction of indicators

(1) $$NDVI_{(t)} = NDVI_{min} + (NDVI_{max} - NDVI_{min})\left\{\frac{1}{1+\exp(-mS(t-S))} + \frac{1}{1+\exp(-mA(t-A))} - 1\right\}$$

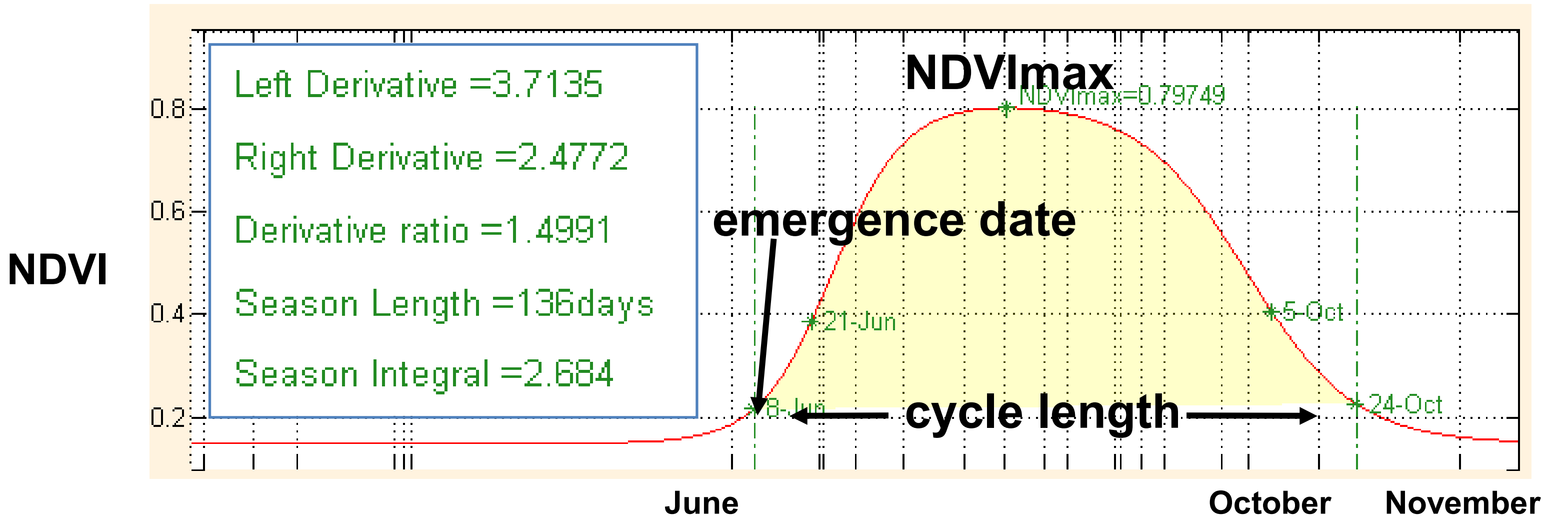
Part 1 : Cartography - Irrigated surfaces

1 - Early detection of summer crops

2 - Discrimination of irrigated areas

→ Summer crops phenological indicators

NDVI time serie on maize field



Interpolation by the double sigmoid

→ **NDVI Tool :** interfaced program for automated extraction of indicators

Calculation of indicators

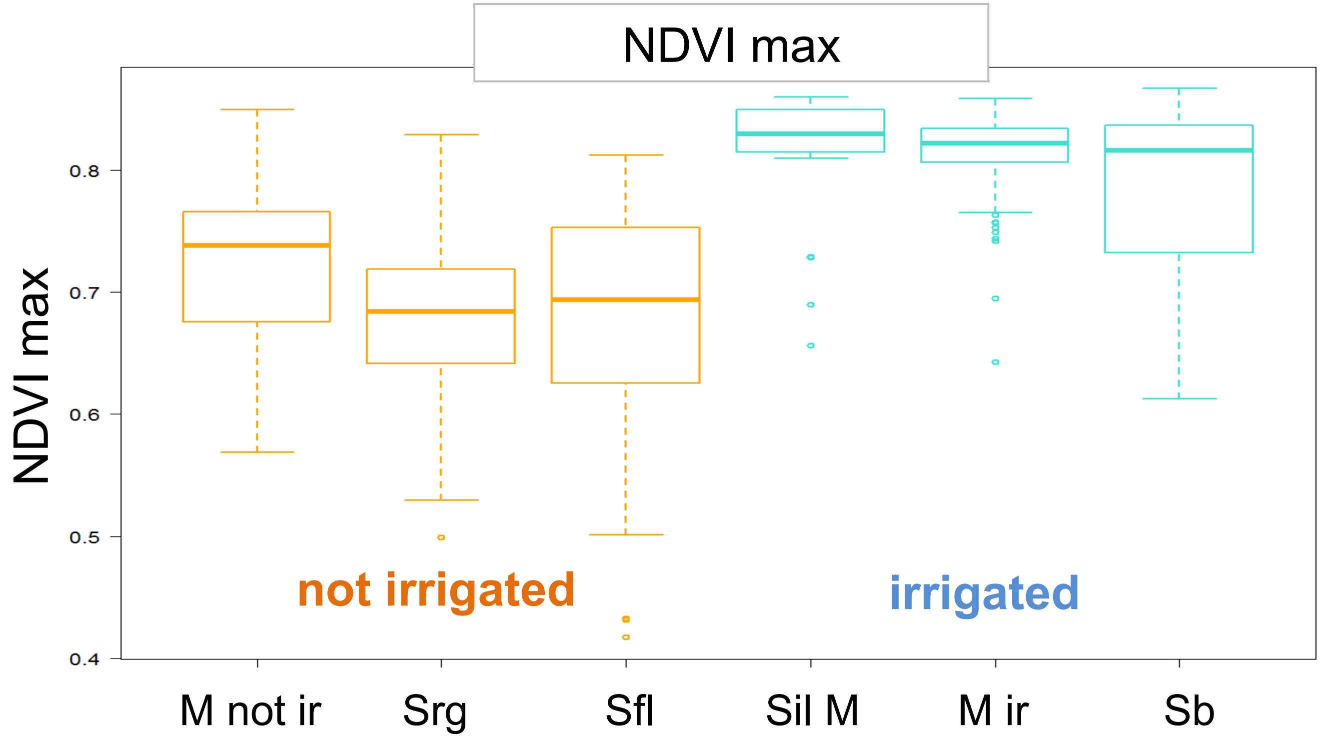
→ emergence date, growth speed, cycle length, NDVImax, NDVI daily accumulation

Part 1 : Cartography - Irrigated surfaces

1 - Early detection of summer crops

2 - Discrimination of irrigated areas

→ Summer crops phenological indicators



Maize not irr. Sorghum Sunflower Silage maize Maize Irr. Soybean

Part 1 : Cartography - Irrigated surfaces

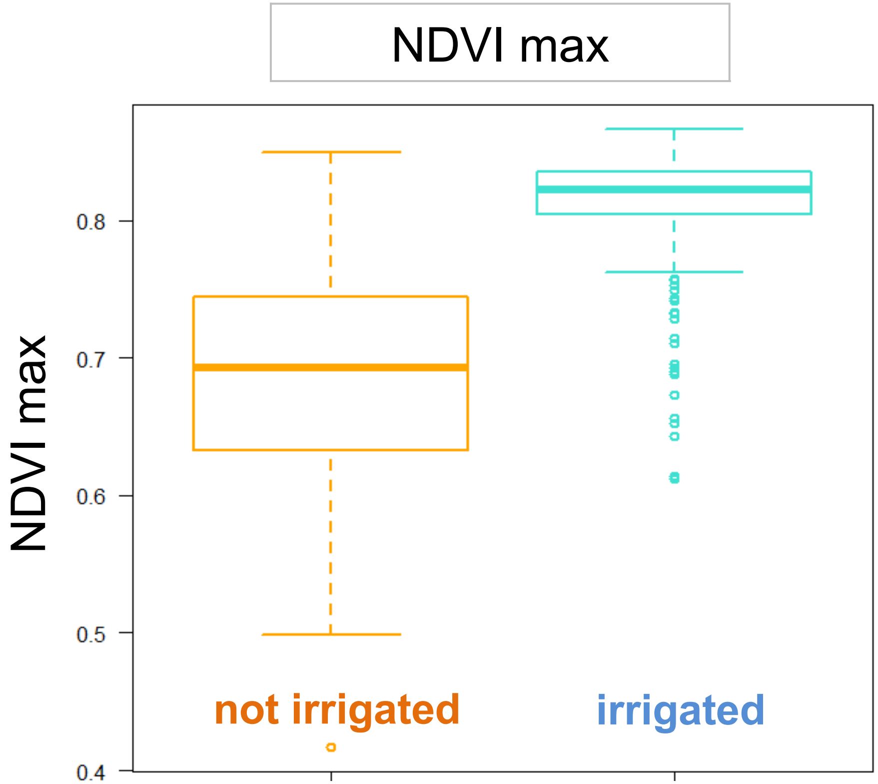
1 - Early detection of summer crops

2 - Discrimination of irrigated areas

→ Summer crops phenological indicators

Classification with NDVImax thresholding

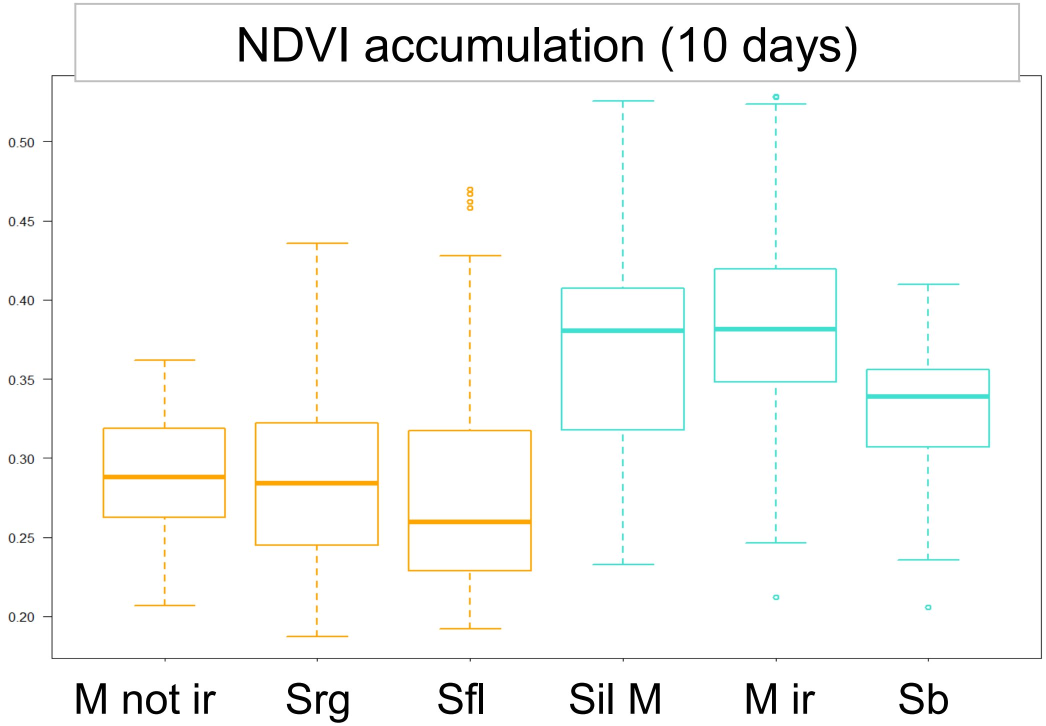
→Validation on test plots
198 irrigated plots, **83.8% extracted**
353 not irrigated plots, **96% extracted**



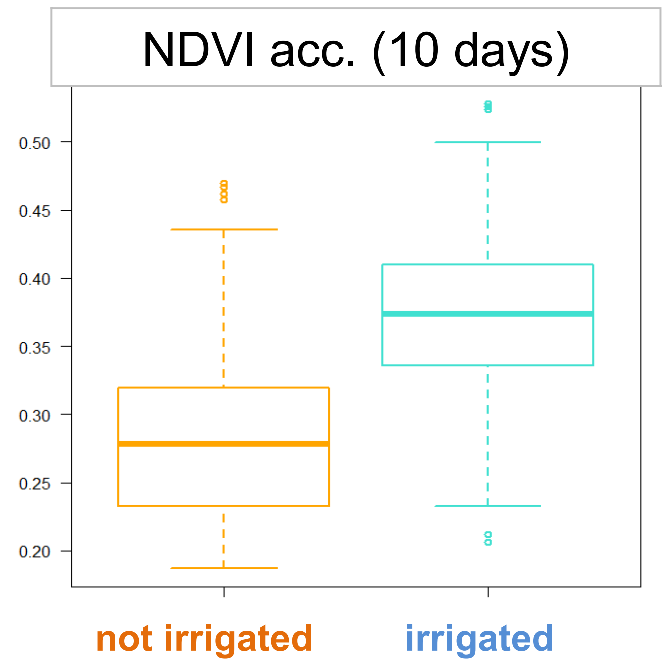
Effective method, but after the end of irrigation period
→ Entire growth cycle is necessary

Part 1 : Cartography - Irrigated surfaces

Detection of irrigated surfaces from the beginning of season

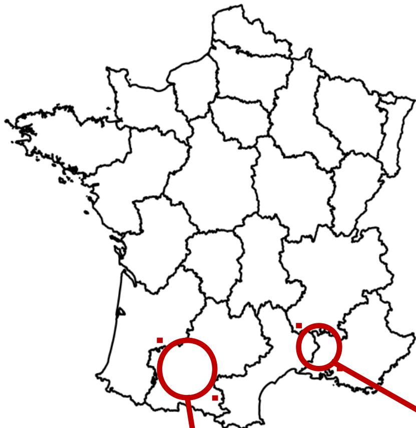


10 days NDVI accumulation
→from the emergence date



some indicators can be calculated during the season
→operational management, near real time

Part 2 : Biophysical variables - Dataset and study area



<u>Satellite data 2013 :</u>

SO → ~25 images from march to october
Formosat2 (8 meter resolution), SPOT4&5, Landsat8, Deimos

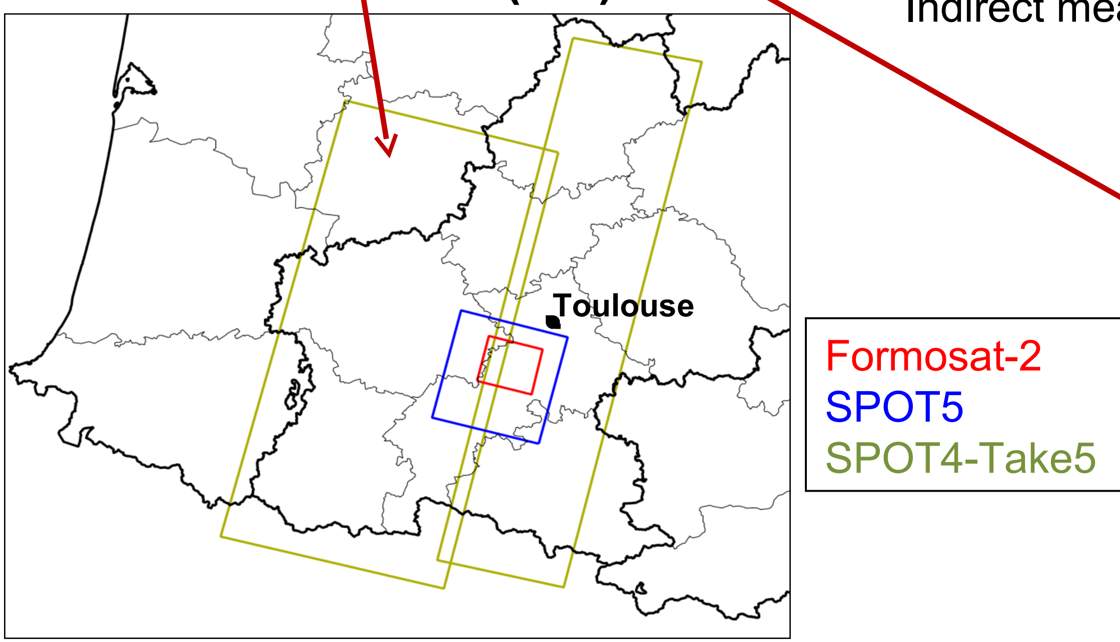
SE → ~25 images from march to september
(SPOT4&5, Landsat7&8)

<u>Field data</u> :

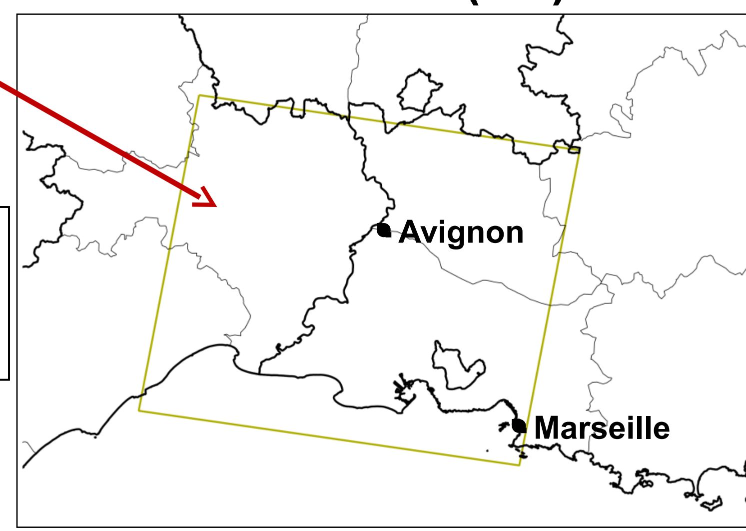
- wheat, maize and sunflower (SO)
- irrigated meadows (SE)

Direct measurement of biomass and yield
Indirect measurement of GAI, fAPAR, FCover

South West (SO)



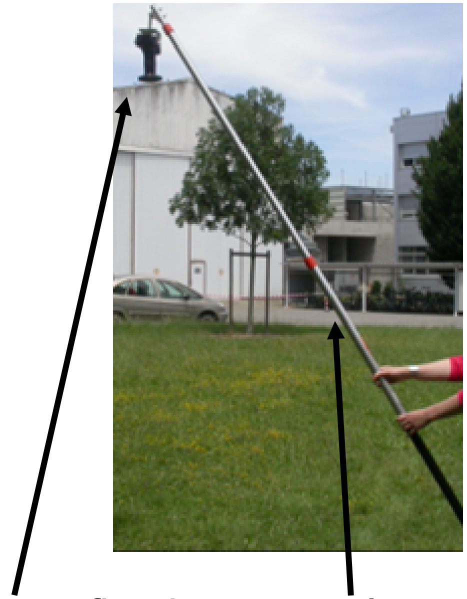
South East (SE)



Part 2 : Biophysical variables – GAI fAPAR Fcover

Estimation of GAI, fAPAR, Fcover : Field campaign 2013

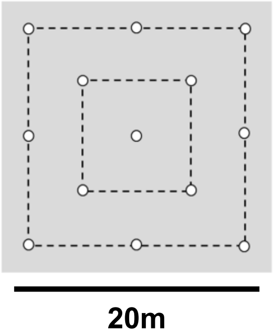
1 - In-situ DHPs acquisition
(**D**igital **H**emispheric **P**hotography)



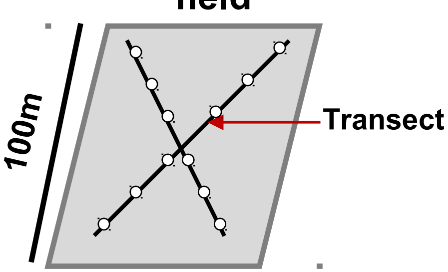
camera fixed on a « pole »
→ Stay above the vegetation

South West :
Elementary Sampling Unit (ESU)
→VALERI protocol (1)

20m x 20m → 12-13 DHPs



South East :
2 transects crossed for fields



(1) http://w3.avignon.inra.fr/valeri/

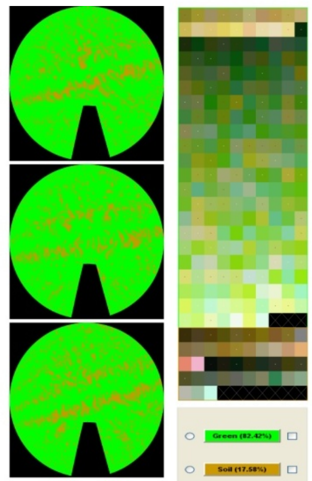
Part 2 : Biophysical variables – GAI fAPAR Fcover

<u>Estimation of GAI, fAPAR, Fcover : Field campaign 2013</u>

1 - In-situ DHPs acquisition

2 – Processing DHPs with Can_Eye software (1)

Classification process →



→

Output variables

- GAI
- FAPAR
- FCOVER

In-situ data :

Culture	Period	Sampling dates	ESUs
Wheat (**SO**)	April-July	7	5
Maize (**SO**)	May-October	8-12	9
Sunflower (**SO**)	May-September	5-6	11
Irrigated meadow (**SE**)	February-September	6-15	12

(1) http://www6.paca.inra.fr/can-eye

Part 2 : Biophysical variables – GAI fAPAR Fcover

Estimation of GAI, fAPAR, Fcover : Field campaign 2013

1 - In-situ DHPs acquisition

2 – Processing DHPs with Can_Eye software

Estimation of GAI, fAPAR, Fcover : from satellite images

→ **BVNET tool** (Biophysical Variable Neural NETwork)
Developed by INRA (EMMAH, Avignon)

- neural network approach
- learning with simulations from a physically-based canopy and radiative transfer model (SAIL/PROSAIL)
- requires no prior calibration with in-situ measurements.

Part 2 : Biophysical variables – GAI fAPAR Fcover

Estimation of GAI, fAPAR, Fcover : Field campaign 2013

1 - In-situ DHPs acquisition

2 – Processing DHPs with Can_Eye software

→ **Comparing in-situ measurements and satellite estimation of GAI, FAPAR, FCOVER**

Estimation of GAI, fAPAR, Fcover : from satellite images

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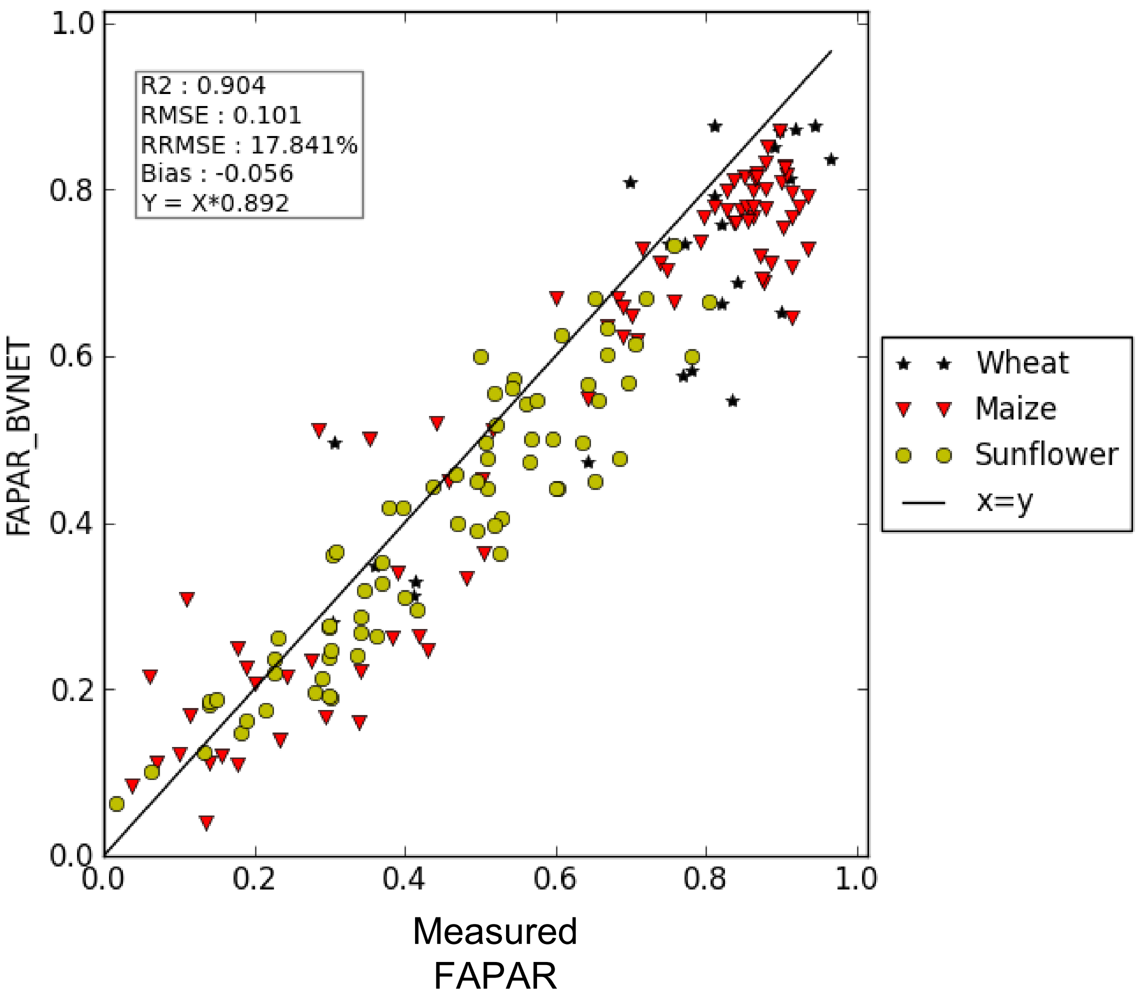
Part 2 : Biophysical variables – GAI fAPAR Fcover

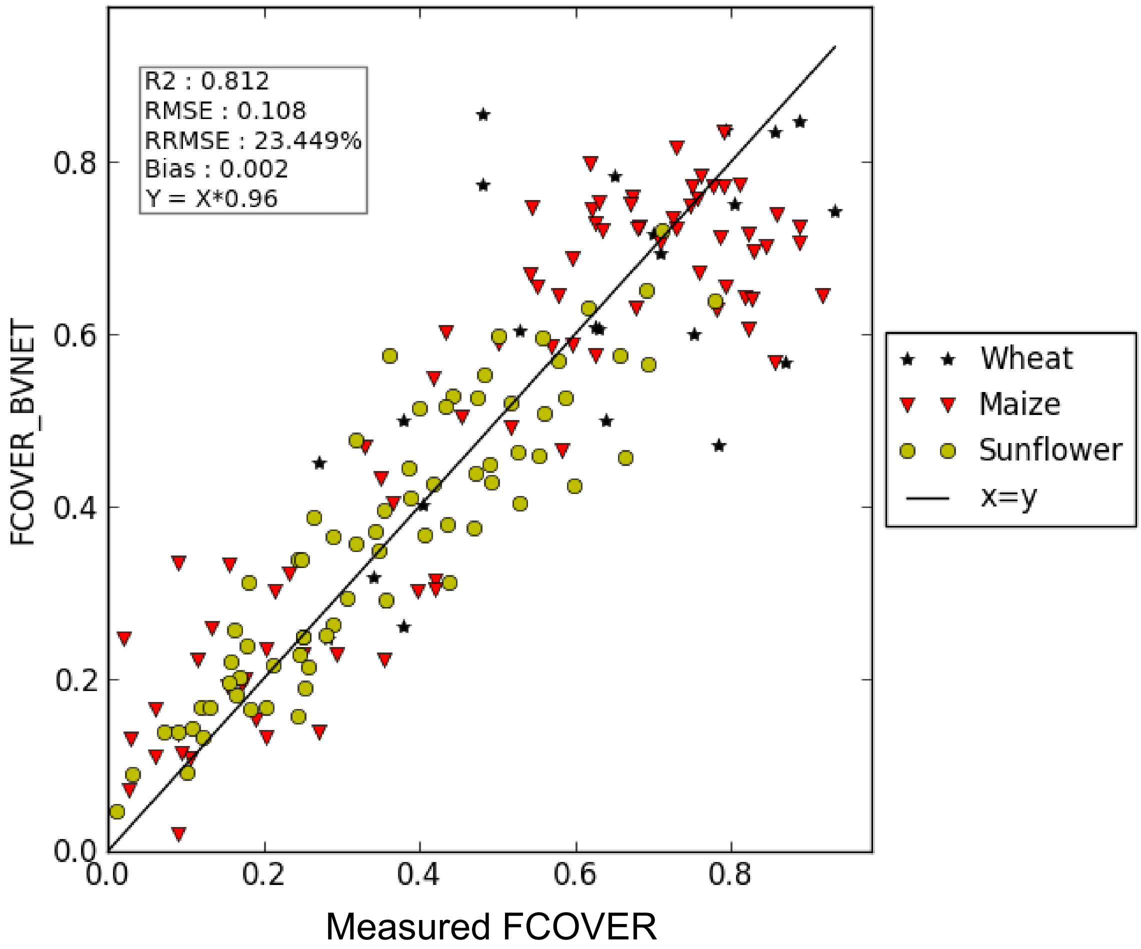
Validation FAPAR : South West site



	Culture	R^2	RRMSE
fAPAR	WHEAT	0.74	17.8 %
	MAIZE	0.92	16.8 %
	SUNFLOWER	0.87	18.8 %

Part 2 : Biophysical variables – GAI fAPAR Fcover

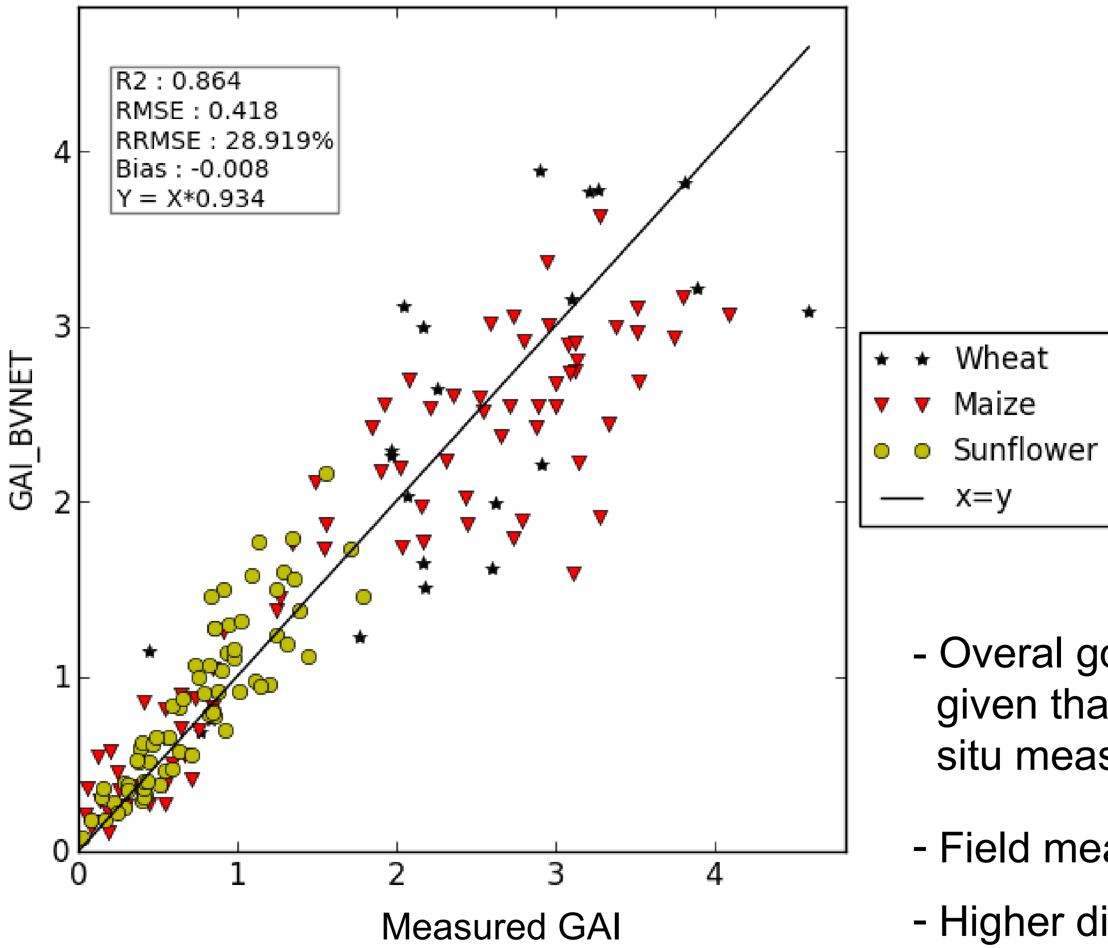
Validation FCOVER : South West site



	Culture	R^2	RRMSE
fAPAR	WHEAT	0.74	17.8 %
	MAIZE	0.92	16.8 %
	SUNFLOWER	0.87	18.8 %
FCover	WHEAT	0.47	25.9 %
	MAIZE	0.83	22.2 %
	SUNFLOWER	0.87	21.7%

Part 2 : Biophysical variables – GAI fAPAR Fcover

Validation GAI : South West site



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	SUNFLOWER	0.87	18.8 %
FCover	WHEAT	0.47	25.9 %
	MAIZE	0.83	22.2 %
	SUNFLOWER	0.87	21.7%
GAI	WHEAT	0.68	28.2 %
	MAIZE	0.87	25.2 %
	SUNFLOWER	0.79	31.8 %

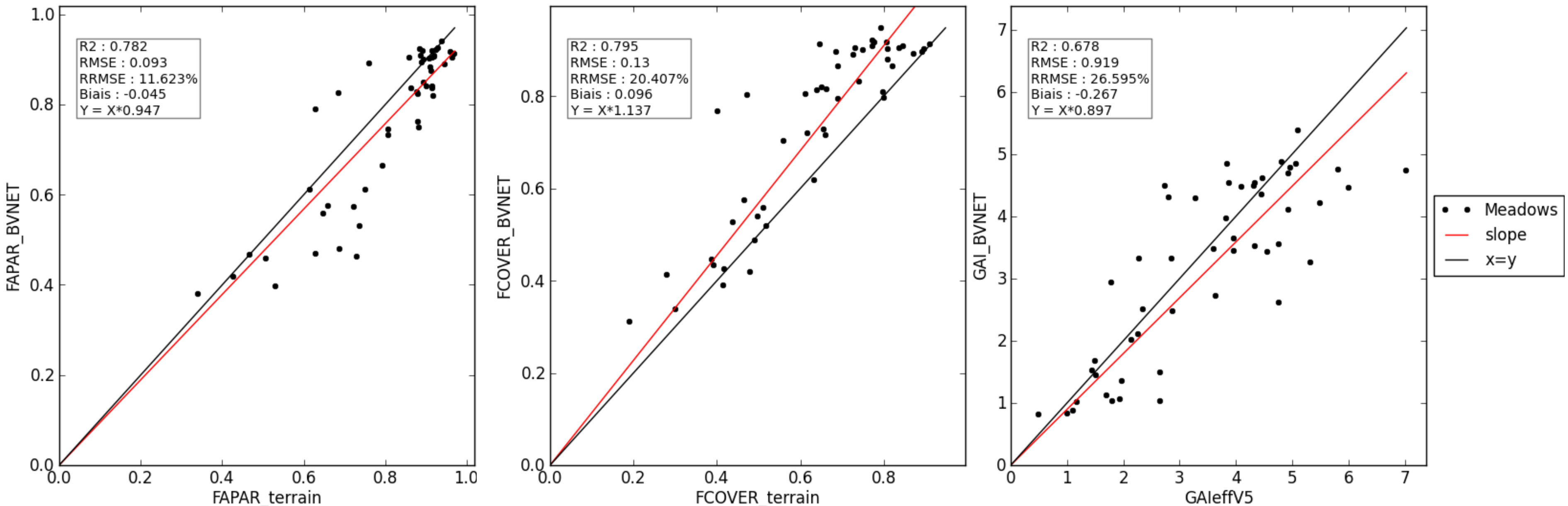
- Overal good correlation for all crops given that BVNET is not calibrated with in-situ measurement
- Field measurement are sometimes difficult
- Higher dispersion for GAI>2 saturation effect of remote sensing signal

Part 2 : Biophysical variables – GAI fAPAR Fcover

Validation BVNET : South East site

First results
Irrigated meadows
SPOT4 images from april to june

Variable	R^2	RRMSE
FAPAR	0.78	11.6%
FCOVER	0.79	20.4%
GAI	0.68	26.6%



Different dynamic → several harvest a year

Estimation of biomass : Field campaign 2013

Total dry biomass

Measure → 5 samples to 1.6m² each ESU

Culture	Nb. plots	Sampling date
Wheat	11 *	July
Maize	7 *	October
Sunflower	32 **	July, August, September (4 dates)

* before harvest (maximum biomass for grains)

** before harvest and during growth cycle

Estimation of biomass : Field campaign 2013

Total dry biomass

Measure → 5 samples to 1.6m² each ESU

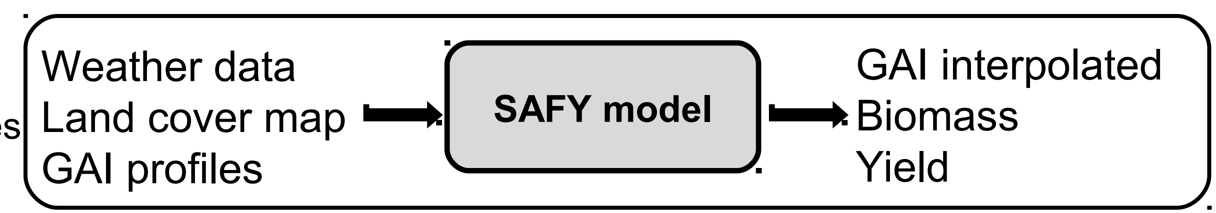
Culture	Nb. plots	Sampling date
Wheat	11 *	July
Maize	7 *	October
Sunflower	32 **	July, August, September (4 dates)

Estimation of biomass : from satellite images

SAFY

Simple Algorithm For Yield Estimates

Duchemin et al. 2008 – CESBIO



- Limited number of simulated processes and parameters
- Adapted to the use of remote sensing data
- Daily step

Part 2 : Biophysical variables - Biomass

Estimation of biomass : Field campaign 2013

Total dry biomass

Measure → 5 samples to 1.6m² each ESU

Culture	**Nb. plots**	**Sampling date**
Wheat	11 *	July
Maize	7 *	October
Sunflower	32 **	July, August, September (4 dates)

→ **Comparing in-situ measurements and satellite estimation of Biomass**

Estimation of biomass : from satellite images

SAFY

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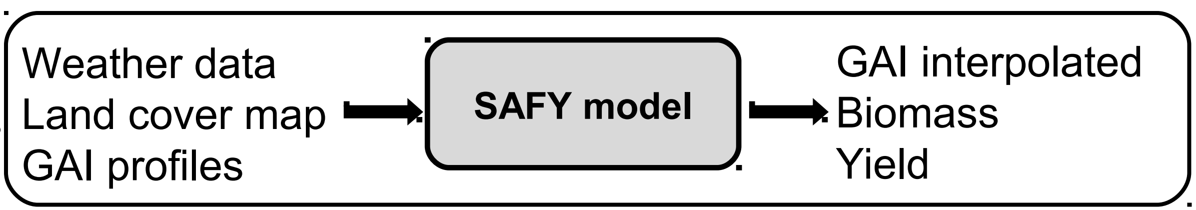

- Limited number of simulated processes and parameters
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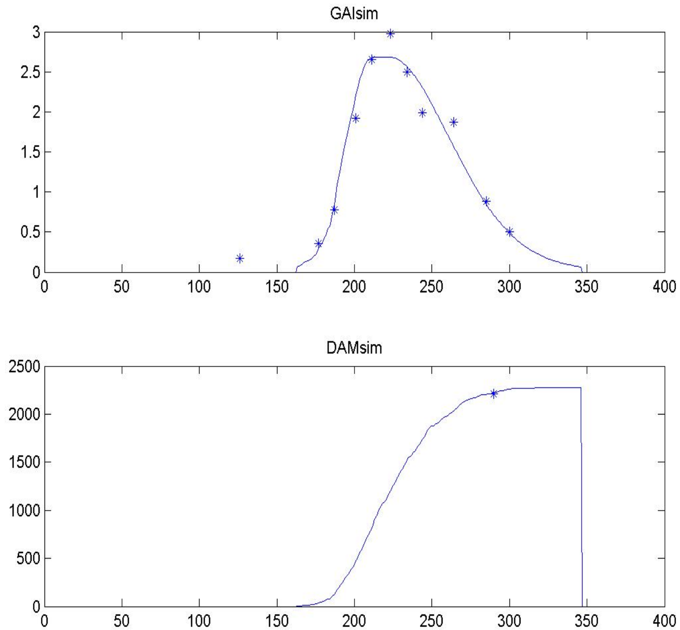
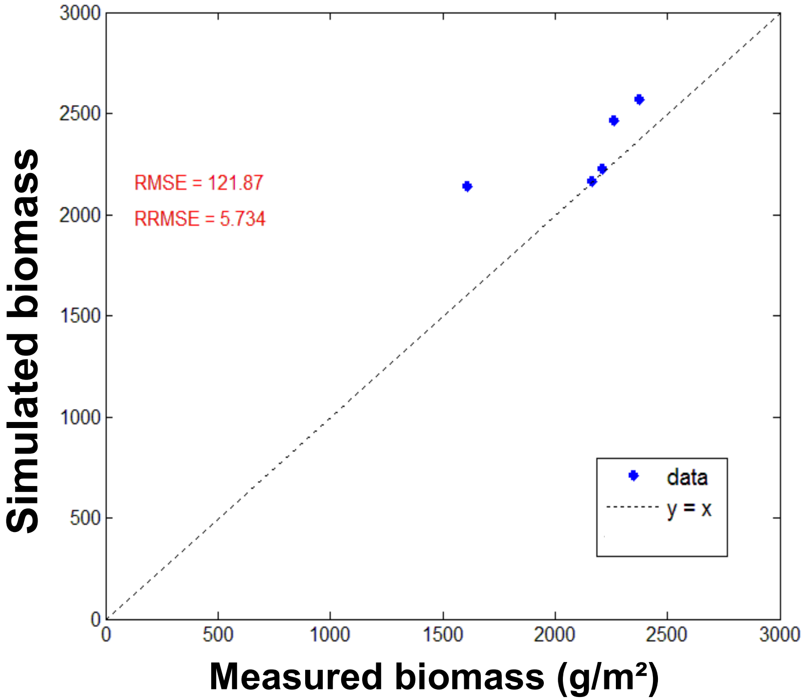
- Daily step

Part 2 : Biophysical variables - Biomass

Validation biomass : South West site

Promising first results : maize biomass, Formosat-2 images





Validation on work for sunflower and wheat

Conclusions and perspectives

Cartography :

- possible detection of summer crops from june
- good results for discrimination of irrigated and not irrigated crops

Biophysical variables :

- globally good results obtained with BVNET tool for the two sites
- biomass estimation : promising results with SAFY

→ **Operational methods in perspective of Sentinel-2 mission**

Perspectives

Test methods robustness :

- validate mapping of summer crops and irrigated surfaces with 2013 data
- database of type NDVI profiles (maximum NDVI, NDVI daily accumulation)
- evaluate classification method without ancillary data (RPG)
- BVNET validation with other years

Validation work :

- validation of yield SAFY estimation
- Validation of ETR and water supplies with SAFY+FAO56

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CESBIO

cnes

Thank you for your attention

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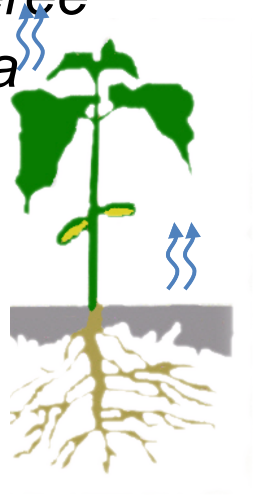
CNES, FEDER, OSEO, Agence de l'eau, CACG, Région Midi-Pyrénées

Méthode FAO-56*

Évapotranspiration : *Quantité d'eau totale transférée du sol vers l'atmosphère par l'évaporation (sol) et par la transpiration (plantes)*



Evapotranspiration de référence (ET_0)

Evapotranspiration réelle (ET_R)

single crop coefficient : $ET_R = Kc \ . \ ET_0$

dual crop coefficient : $ET_R = Ke \ . \ ET_0 + Kcb \ . \ ET_0$

Evaporation Transpiration

* Allen et al. (1998)

Modèle SAFYE

Modèle à réservoirs

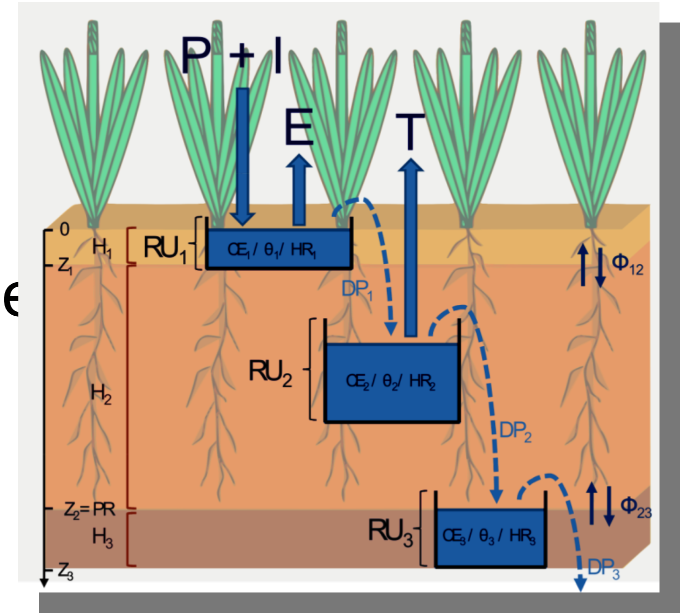
3 couches de sols (surface, racinaire, profonde)

Bilan hydrique :

- Entrées : P, I
- Sorties : ET_R, D

Calcul du stress hydrique

- Impacte la croissance de biomasse



$$\Delta DAM = ELUE \times Ft(Ta) \times Wts \times APAR$$

Avec : F_T = Stress thermique

Wts = Stress hydrique

APAR = FAPAR x ε_c x Rg

→ Stress hydrique découplé de la ELUE (≠ SAFY)