

**ESA–MOST Dragon Cooperation**

中国科技部-欧洲空间局“龙计划”合作

## **2017 DRAGON 4 SYMPOSIUM**

2017年“龙计划”四期学术研讨会

# **EXPLOITATION OF MULTITEMPORAL AND MULTISENSOR EARTH OBSERVATION DATA FOR ARABLE CROP CLASSIFICATION AND YIELD ASSESSMENT AT THE FARM SCALE**

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26–30 June 2017 | Copenhagen, Denmark

2017年6月26-30日, 丹麦 哥本哈根

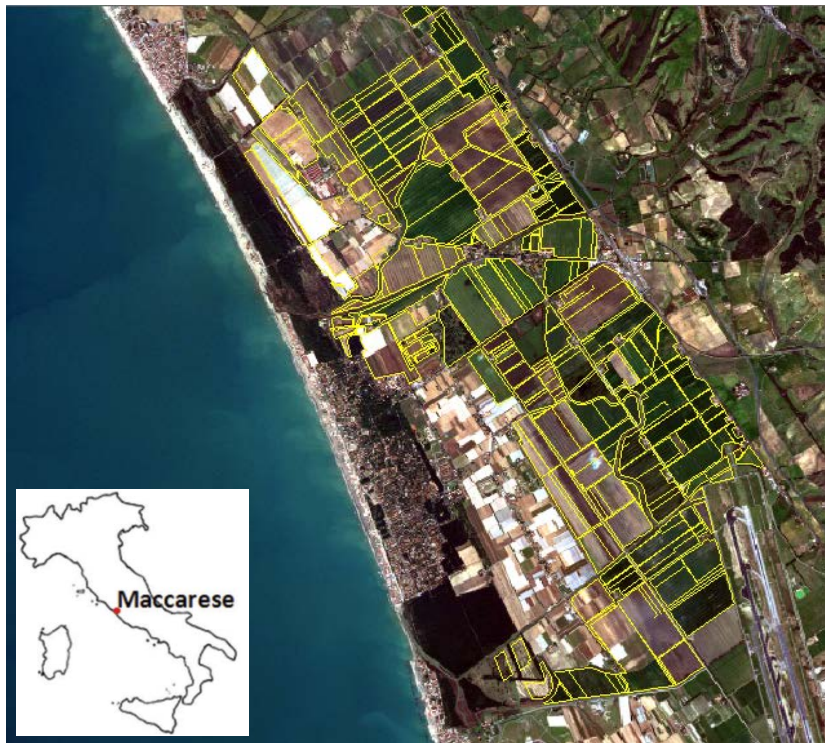
# Topic 1 of the Dragon4 project ID32275

**Algorithm Development Exploiting Multitemporal and multisensor Satellite data for improving crop classification, biophysical and agronomic variables retrieval and yield prediction (ADEMS)**

- WP1: Crop classification
- WP2: Retrieval from optical and SAR data
- WP3: Defining errors and uncertainties
- WP4: Data assimilation into crop models
- WP5: Crop yield and quality estimation
- WP6 : Core field validation



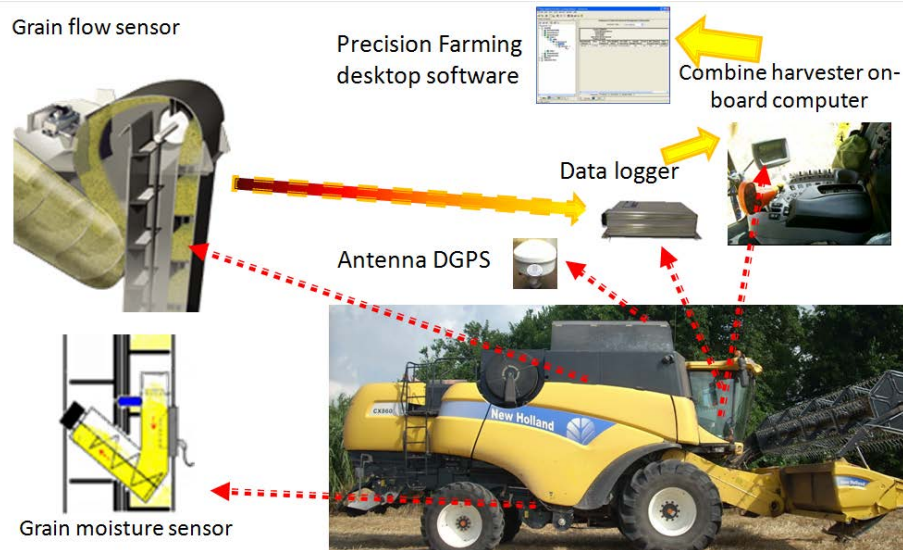
# Maccarese test site Central Italy



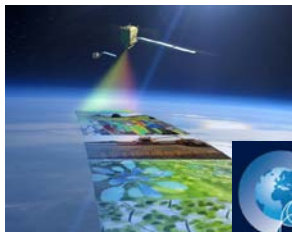
Large private farm 3200 ha flat coastal area

□ large fields (15 – 100 ha plots)

□ precision farming equipment



# Maccarese test site Central Italy



## Crops

Durum wheat

Winter wheat

Maize

Alfalfa

Ryegrass

Triticale

Barley

Rapeseed

Broad bean

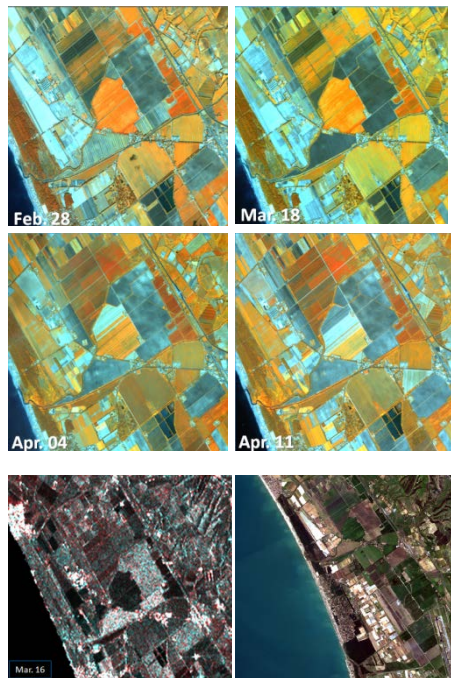
Pea

Carrot

Potato

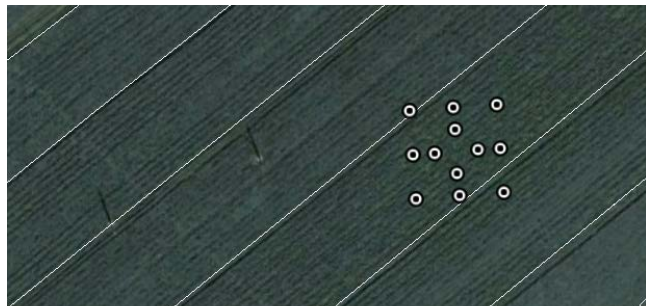


# Maccarese 2015 satellite images dataset



	CSK ping-pong (HH-VV)	CSK Himage	Alos (HH-VV)	RapidEye (5m, 5 ch)	Landsat	ZY-3 (6m, 4ch)	Chris	Hyperion	Ground truth (*)
Jan.	03, 11, 23, 27	Four images/ month	7, 12, 19	28	6				11, 13, 27, 28
Feb.	28		11, 18, 27		23				24
Mar.	08, 16, 24		9, 31	18		23	13		3, 20
Apr.	10		1, 6, 10	04, 11	12				
May	03		11, 13, 18, 22, 27, 29	11	14, 30			7	
June	20		2, 10, 17, 24, 29	3, 10, 30 <sup>h</sup>					30
July	06		3	5, 15	15			11	7
<b>Total n.</b>	<b>12</b>		<b>23</b>	<b>10 (5)</b>	<b>6</b>	<b>1</b>	<b>2</b>		

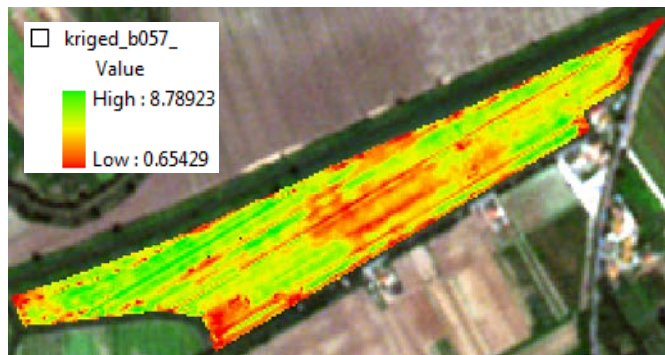
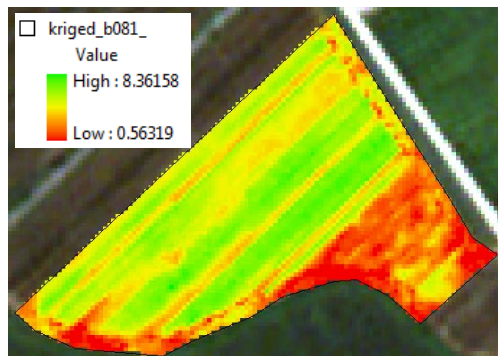
## Maccarese 2015 ground data



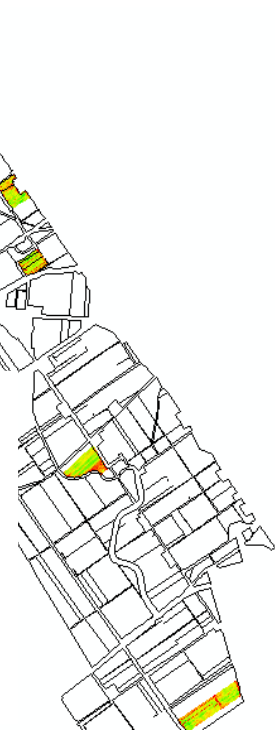
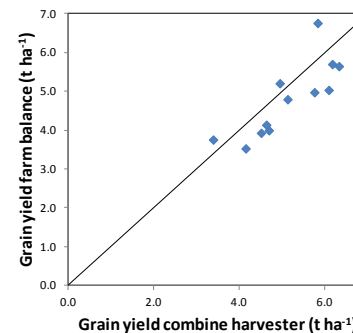
Li-Cor Plant Canopy Analyzer  
LAI-2000, chlorophyll (Dualox),  
biomass



# Wheat yield ground data from combine harvester



Raw data correction  
Local variogram  
Block kriging



Classification of land was done using:

- 10 images **RapidEye** (free clouds);
- Field data provided by the Maccaresse farm

Four types of crops were identified:

- Winter crops
- Summer crops
- Pastures
- No cultivation.

Subsequently, 6 other classes of coverage were identified in the study area: Forest, Sea, Swamp, Beach, Urban and routes, Intensive cultivation.

Supervised classification of Maxima Likelihood was carried out. Identified ROI were used for classification and quality assessment

## IMAGES SET:

Rapideye\_2015-02-28  
 Rapideye\_2015-03-18  
 Rapideye\_2015-04-01  
 Rapideye\_2015-05-11  
 Rapideye\_2015-06-03  
 Rapideye\_2015-06-10  
 Rapideye\_2015-07-05  
 Rapideye\_2015-07-15  
 Rapideye\_2015-08-29  
 Rapideye\_2015-09-10





# Classification

The confusion matrix was computed.

Overall Accuracy:	98,86%
Kappa Coefficient:	0,9678

		Ground Truth (%)										Total
		FOREST	WINTER CROPS	SUMMER CROPS	SEA	NO CULTIVATION	SWAMP	PASTURE	BEACH	URBAN & ROUTES	INTENSIVE CROPS	
Class (%)	FOREST	97.86	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	2.62
	WINTER CROPS	0.14	97.61	0.02	0.00	6.19	0.00	1.04	0.00	0.00	0.00	4.72
	SUMMER CROPS	0.00	0.00	91.13	0.00	0.81	6.09	0.00	0.00	0.00	0.00	2.58
	SEA	0.00	0.00	0.00	99.93	0.00	0.00	0.00	0.00	0.00	0.00	79.87
	NO CULTIVATION	0.37	0.00	0.00	0.00	81.50	13.25	0.08	0.00	0.00	0.00	0.60
	SWAMP	0.00	0.00	0.00	0.00	0.00	66.03	0.00	0.00	0.00	0.00	0.32
	PASTURE	0.00	1.30	0.00	0.00	5.54	0.00	89.66	0.00	0.00	0.00	1.81
	BEACH	0.00	0.00	0.00	0.01	0.00	0.00	0.00	92.67	0.00	0.00	0.61
	URBAN & ROUTES	0.06	0.00	0.00	0.06	0.00	0.75	0.27	6.45	89.90	0.08	1.32
	INTENSIVE CROPS	1.57	1.09	8.85	0.00	5.95	13.89	8.92	0.88	10.10	99.92	5.55
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

## Classification

Clump filters were applied to crop classes to improve visualization.

Classes of interest: winter crops, summer crops, pastures were exported as masks.

A following supervised classification of maximum likelihood was applied to identify the types of crops within each class:

- *Winter crops*: Durum Wheat, Soft Wheat, Triticale, Barley
- *Summer crops*: Corn, Corn Silage, Corn ear Paste.
- *Pastures*: Alfalfa, Vicia, Grass.



# Classification

## Winter Crops – Confusion Matrix

CLASS		Ground Truth (Pixels)				TOTAL
Class (Pixels)	barley	barley	soft wheat	durum wheat	triticale	
	barley	100.00	0.00	0.00	7.21	15.78
	soft wheat	0.00	82.53	0.00	0.00	12.41
	durum wheat	0.00	0.00	98.25	13.09	47.06
	triticale	0.00	17.47	1.75	79.70	24.74
Total		100.00	100.00	100.00	100.00	100.00

Overall Accuracy: 91,16%

Kappa Coefficient: 0,8709

## Summer Crops – Confusion Matrix

CLASS		Ground Truth (Pixels)			TOTAL
Class (Pixels)	corn silage	corn silage	corn paste	corn	
	corn silage	100.00	0.00	0.00	50.30
	corn paste	0.00	79.32	0.42	24.66
	corn	0.00	20.68	99.58	25.04
Total		100.00	100.00	100.00	100.00

Overall Accuracy: 94%

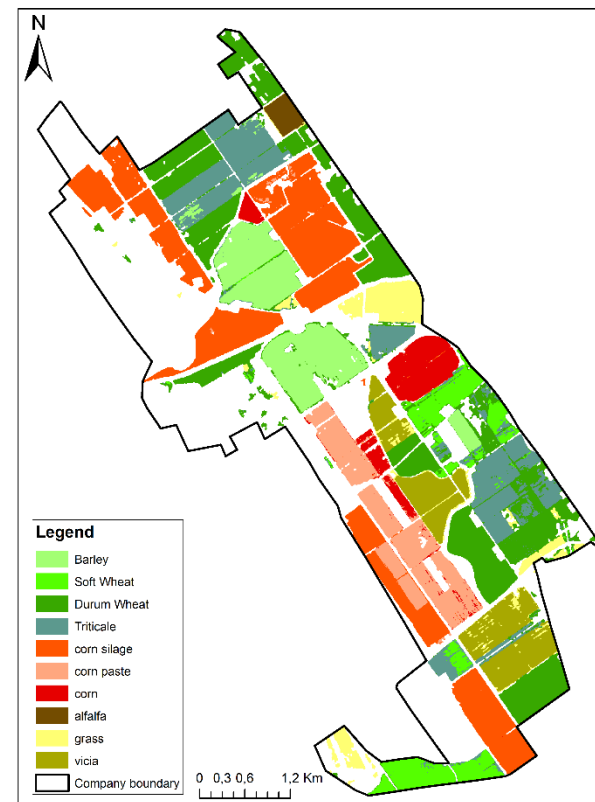
Kappa Coefficient: 0,896

## Pasture – Confusion Matrix

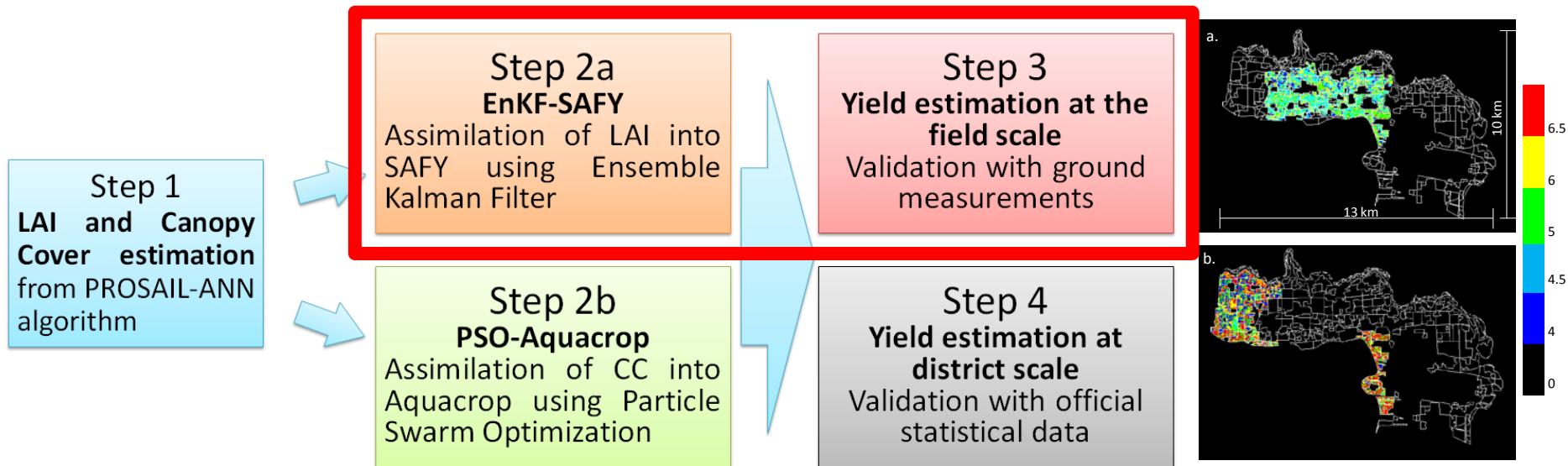
CLASS		Ground Truth (Pixels)			TOTAL
Class (Pixels)	alfalfa	alfalfa	grass	vicia	
	alfalfa	100.00	0.00	0.00	19.06
	grass	0.00	100.00	1.02	34.38
	vicia	0.00	0.00	98.98	46.56
Total		100.00	100.00	100.00	100.00

Overall Accuracy: 99,52%

Kappa Coefficient: 0,9924



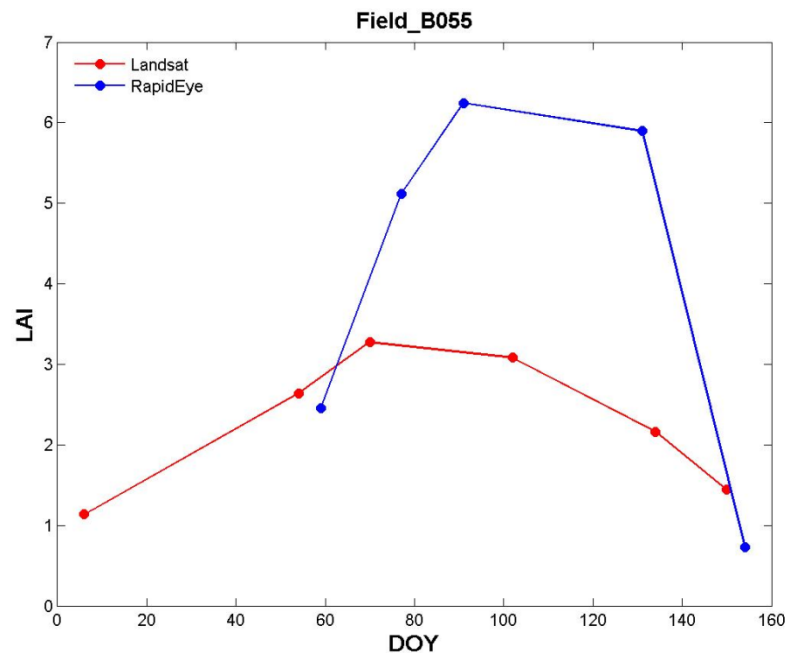
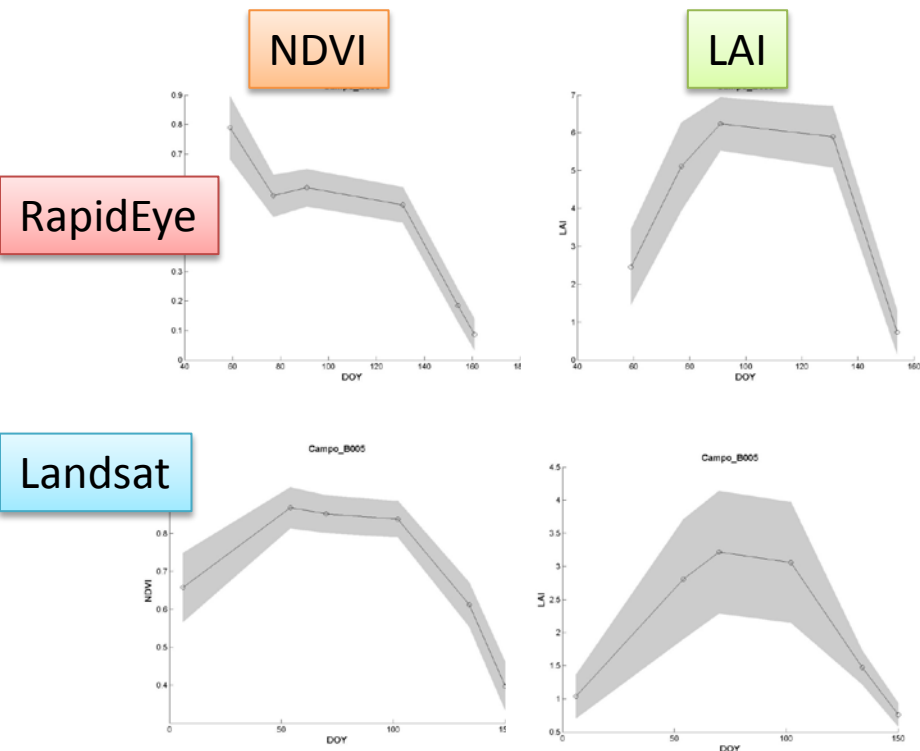
# Yield estimation: data assimilation approach previous work (Dragon3):



Silvestro et al., 2017. Remote Sensing, 9, 509; doi:10.3390/rs9050509

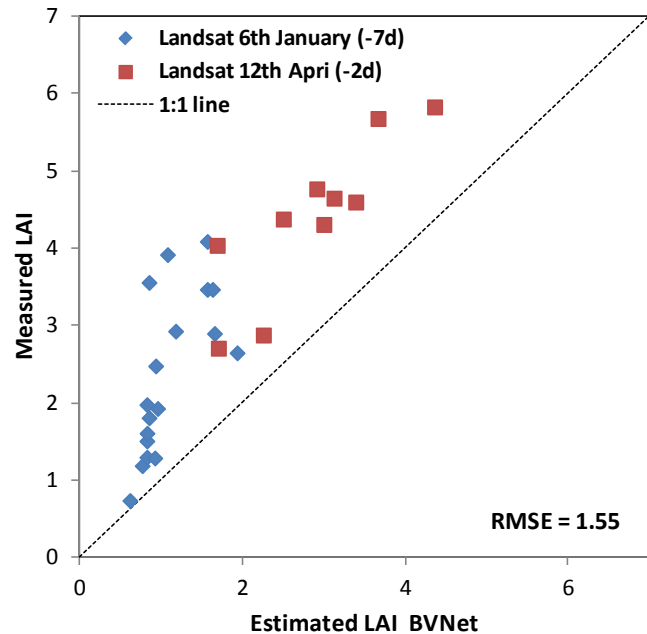


# Maccarese 2015 trend NDVI and estimated LAI field average and std.dev

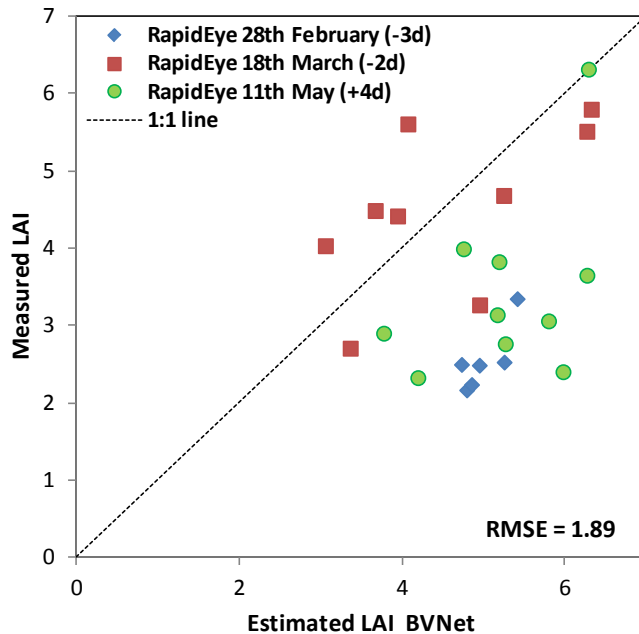


# LAI retrieval using BVNet

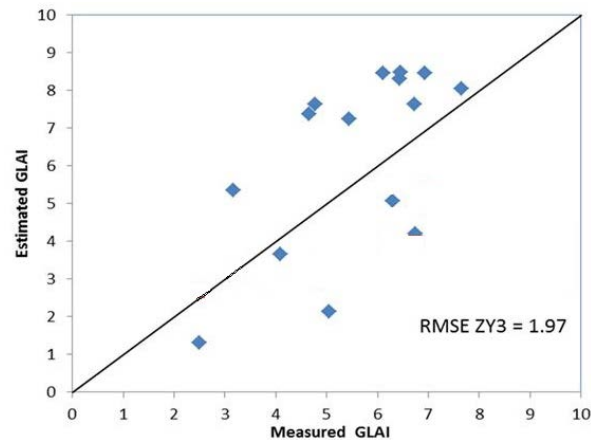
## Landsat 8



## RapidEye

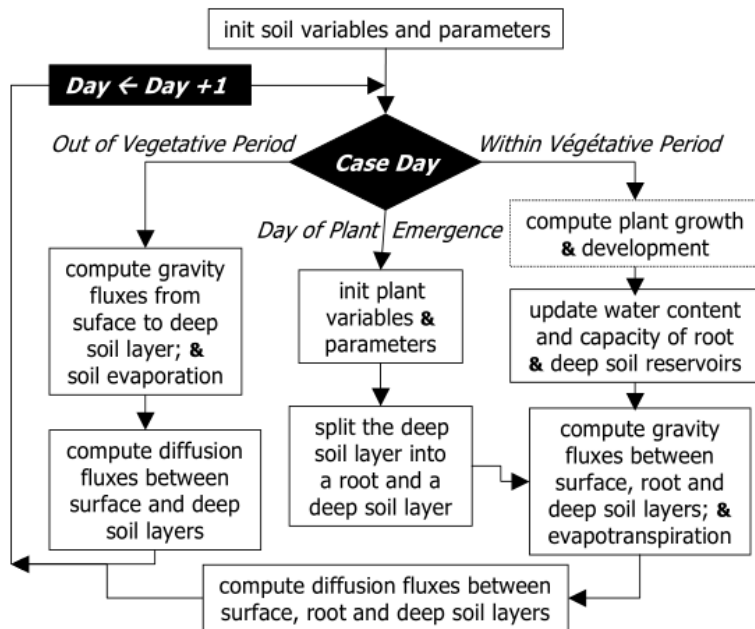


## Zy-3





# SAFY and SAFYE



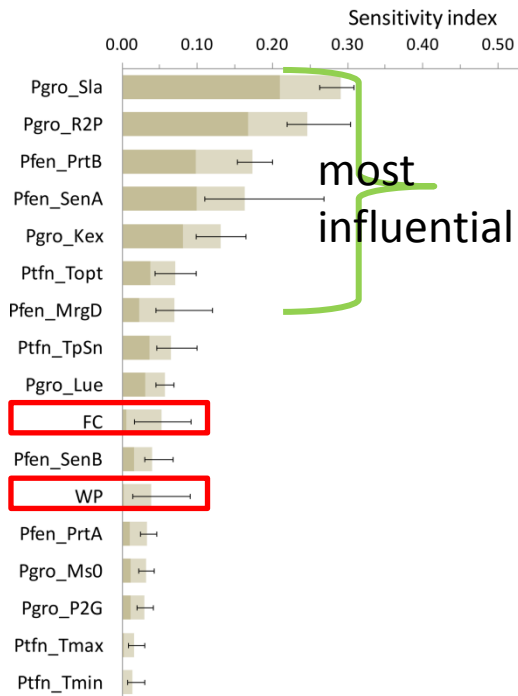
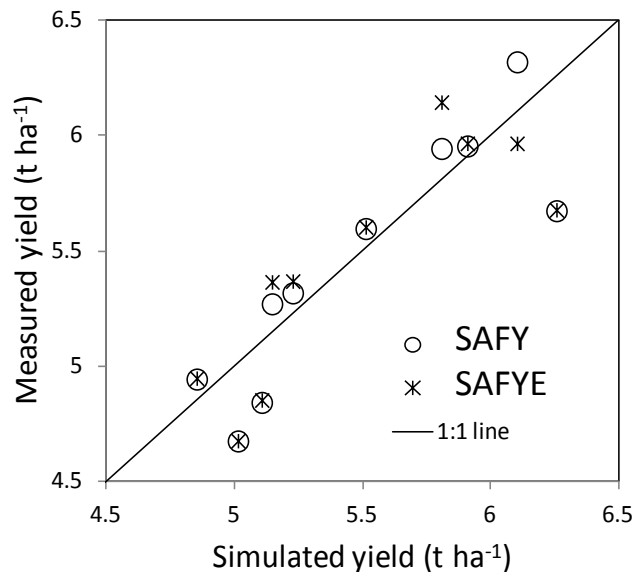
## SAFY

- driving variables: Rad, Temp
- no water balance
- no direct account of crop stress

## SAFYE

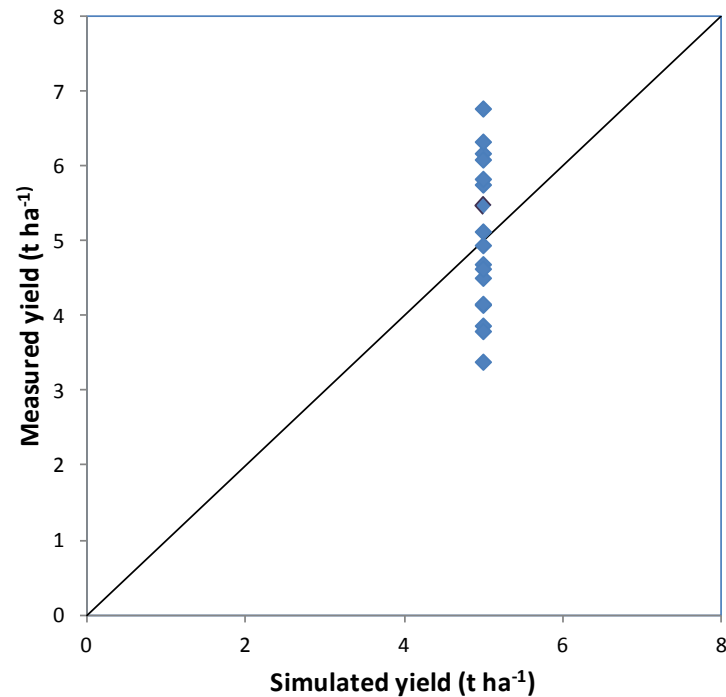
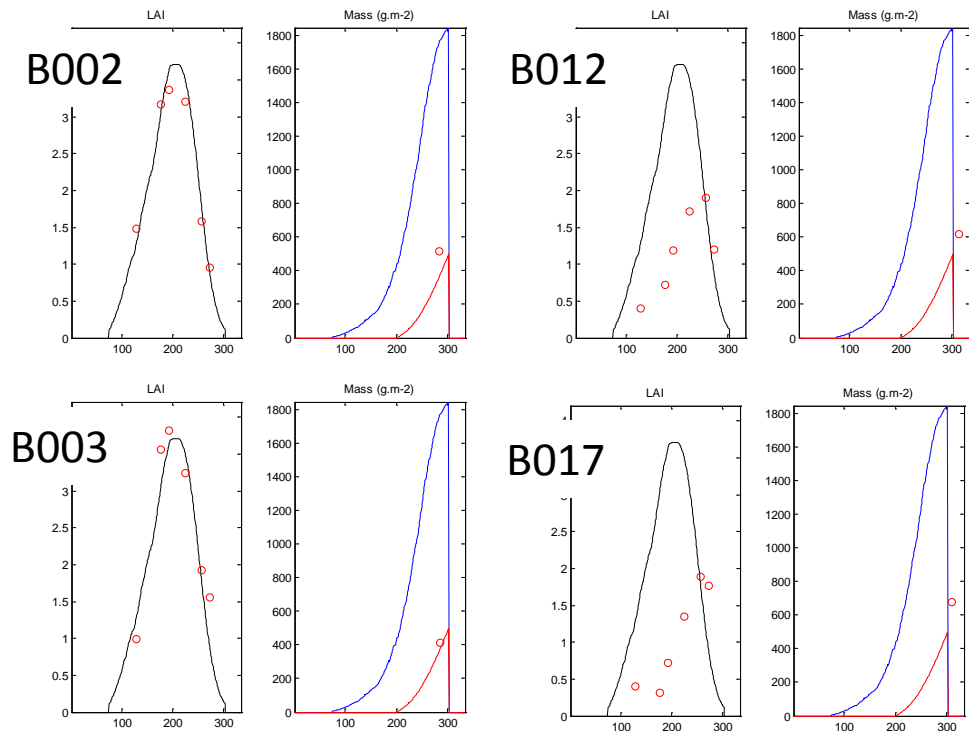
- driving variable: Rad, Temp,  $ET_0$ , soil properties
- water balance according to FAO 56
- takes into account water stress

# Sensitivity analysis: SAFYE additional parameters mostly non-influential



Name of parameter or input variable	Description
Pgro_Sla	Specific Leaf Area (m <sup>2</sup> g <sup>-1</sup> )
Pgro_R2P	Climatic efficiency: ratio of incoming photosynthetically active radiation (PAR) to global radiation
Pfen_SenA	Temperature threshold to start senescence (°C)
Pfen_PrtB	Partition to leaf function parameter 2 (PLb)
Pgro_Kex	Light extinction coefficient in canopy
Pfen_MrgD	Day of the year of emergence

# SAFY calibration dataset Maccarese 2015



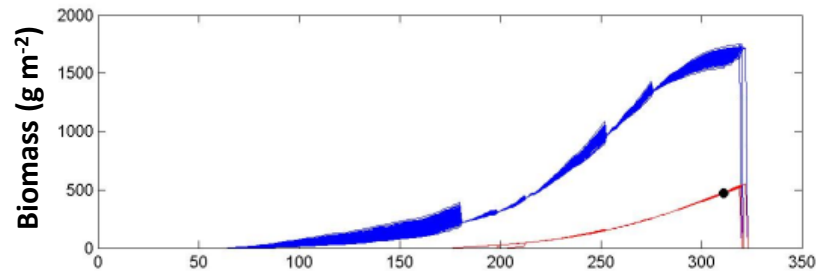
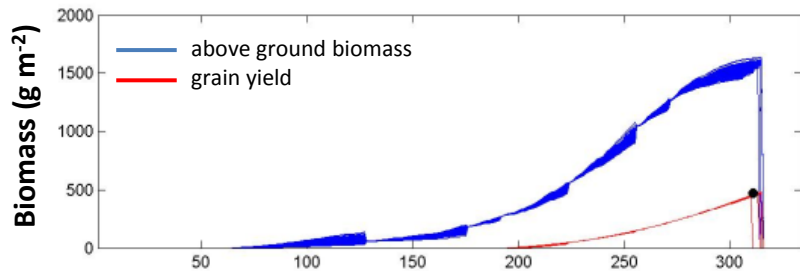
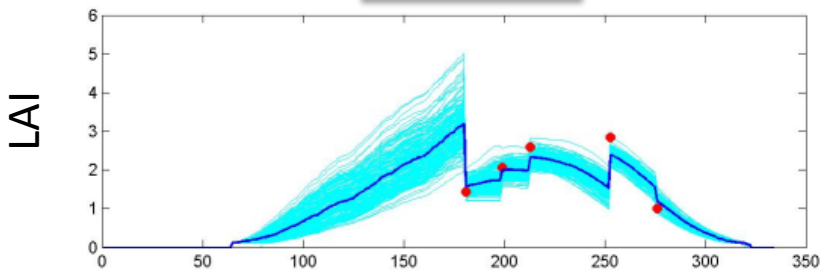
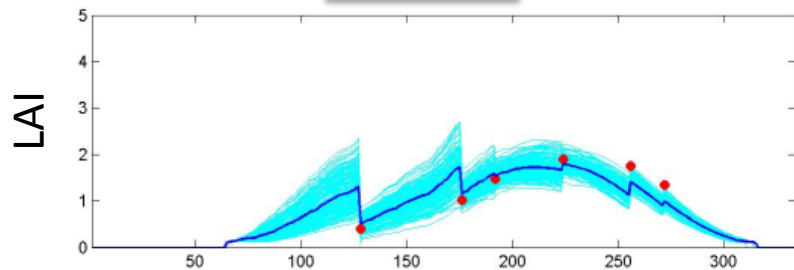


# EnKF assimilation process

Landsat

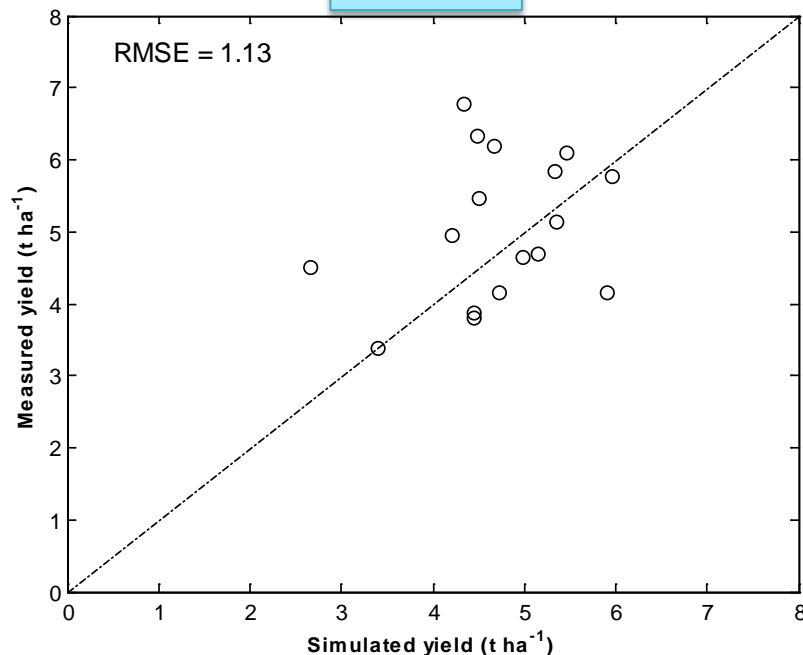
Field B011

RapidEye

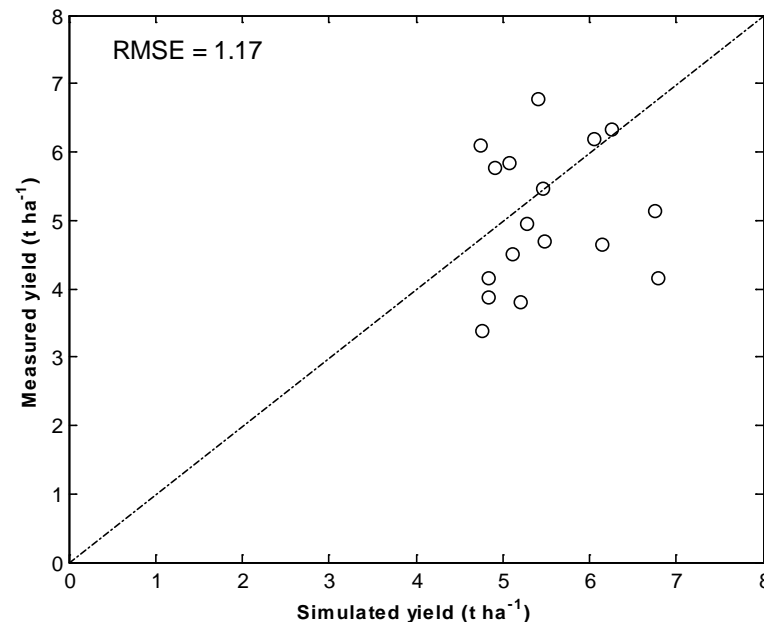


# SAFY assimilation results

Landsat



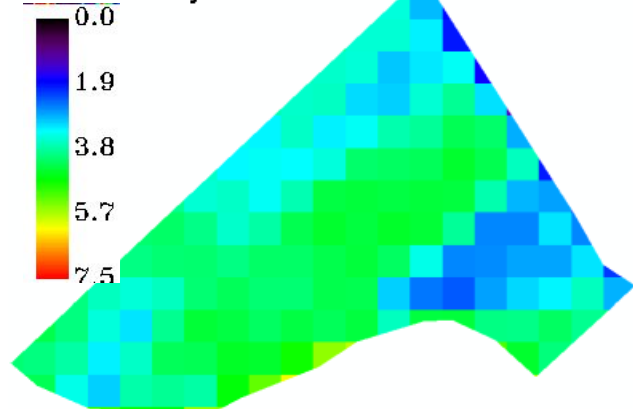
RapidEye



# Capturing within-field spatial variability ?

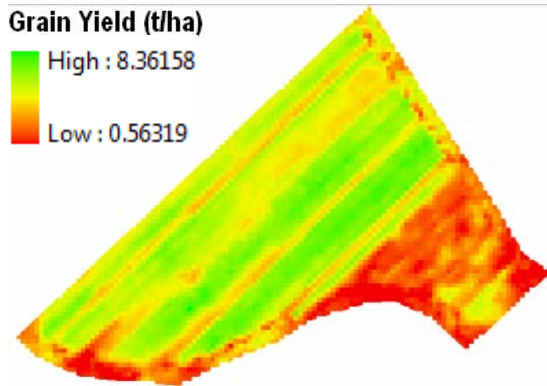
## Landsat

Landsat LAI 14 May

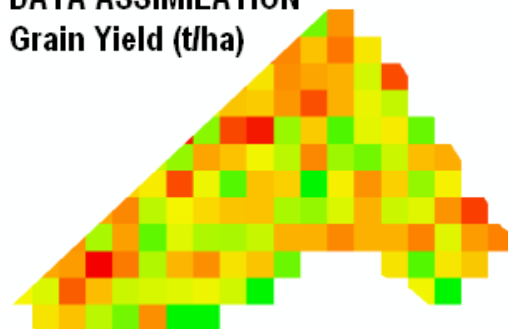


Grain Yield (t/ha)

High : 8.36158  
Low : 0.56319



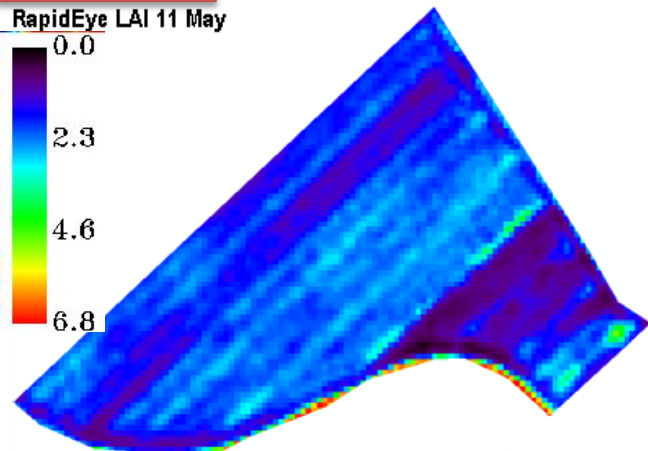
DATA ASSIMILATION  
Grain Yield (t/ha)



## RapidEye

RapidEye LAI 11 May

0.0  
2.3  
4.6  
6.8





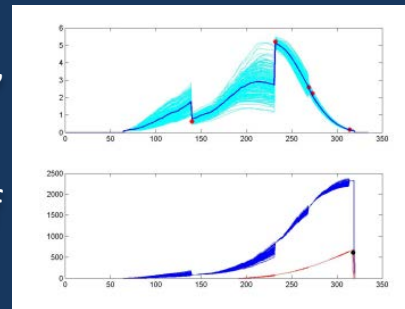
# What is the influence of the number of images available on yield estimation? Test with SAFY synthetic data

20 random parameter extractions

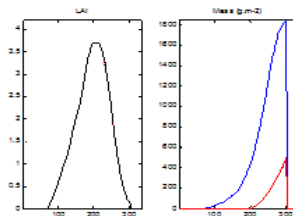
Parameter	Min	Max	media	st deviatc
Pgro_R2P	0.55	0.65	0.6	0.06
Pfen_MrgD	308	328	318	31.8
Pfen_SenA	1272	1472	1372	137.2
Pgro_Sla	0.024	0.028	0.026	0.0026
Pfen_PrtB	0.0012	0.0014	0.0013	0.00013
Pgro_Kex	0.6	0.8	0.77	0.077

Extract a sample of n. LAI "observations"

Use LAI "observations" in the assimilation of SAFY

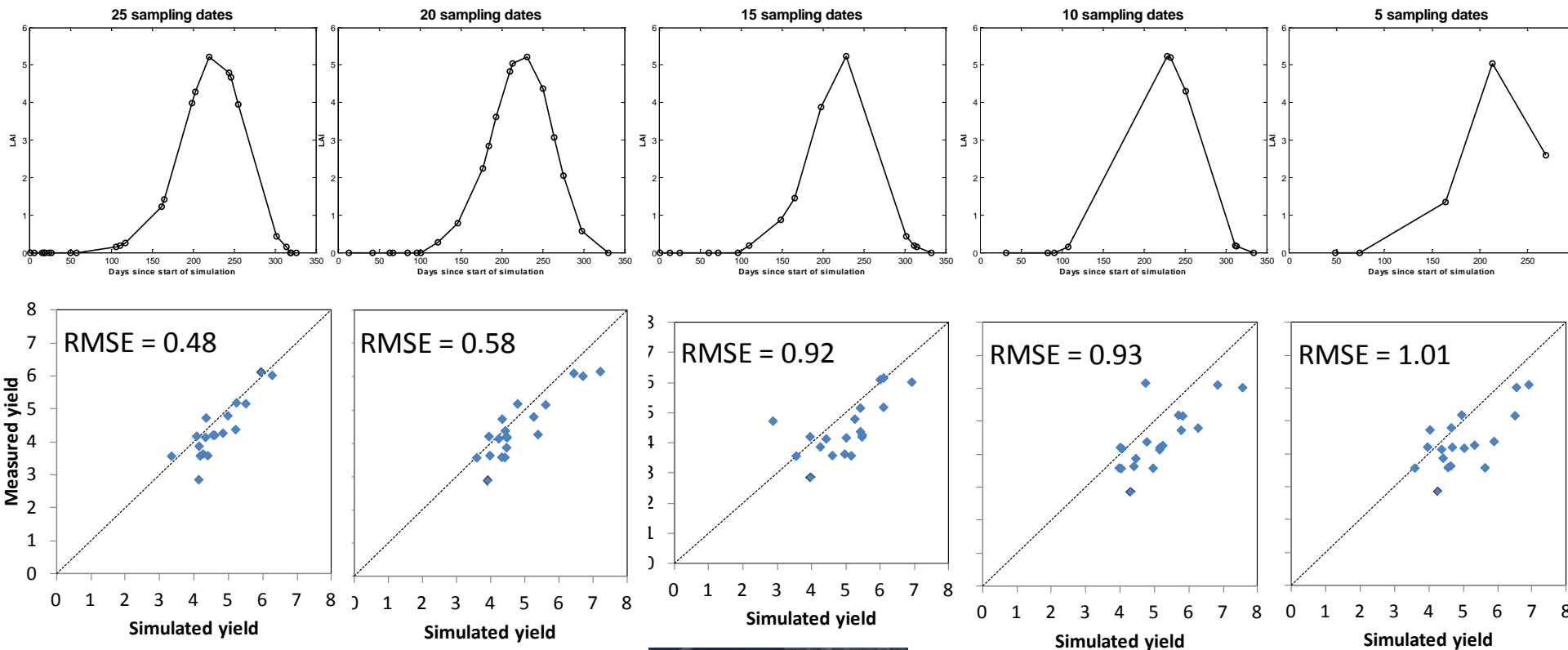


Run SAFY and generate LAI and yields



Compared with yields after assimilation with originally simulated values

# What is the influence of the n. of images available ?



## Conclusions...& work to do for the young scientist

- ❑ use better quality data: radiometric & atmospheric correction, ground data
- ❑ improve the biophysical variables retrieval method: e.g. more efficient use of temporal and spatial constraints information in the ANN algorithm; test with better quality data (Sentinel-2, Venus ?); ground campaigns in 2018
- ❑ carry out a thorough study of the sensitivity of the EnKF method to all contributing factors using synthetic data: n. of observation dates; error on biophysical variables, model calibration....
- ❑ improve SAFYE processes and carry out a more thorough assessment of SAFY vs. SAFYE
- ❑ Develop and test EnKF with SAFY for other crops (e.g. maize)
- ❑ Add N related processes to SAFY in order to address grain quality issues



**THANKS FOR YOUR ATTENTION !**