modextreme

agriculture facing extreme climatic events

European Project n° 613817

Workshop - Brussels

Yield forecasts at EU level

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Cassandra

models for change

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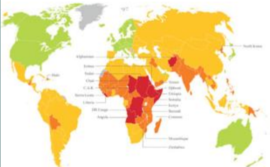
Introduction

- There's an **increasing demand** for crop yield **forecasting systems** in both developed and developing countries
- **Early warnings** in case of poor crop harvests allow indeed governments and other **stakeholders** to
  - assure food imports
  - regulate agricultural markets
- The projected increase in the **frequency and intensity** of extreme weather events is **threatening the reliability** of forecasting services






Objectives

- **Quantifying the reliability** of crop yield forecasts produced using
  - Modelling solutions currently implemented in CGMS
  - Improved (for extreme events) solutions based on
    - Process based models
    - (agro-)climatic indicators
- Define **country- and crop-specific workflows** for yield forecast

General evaluation methodology

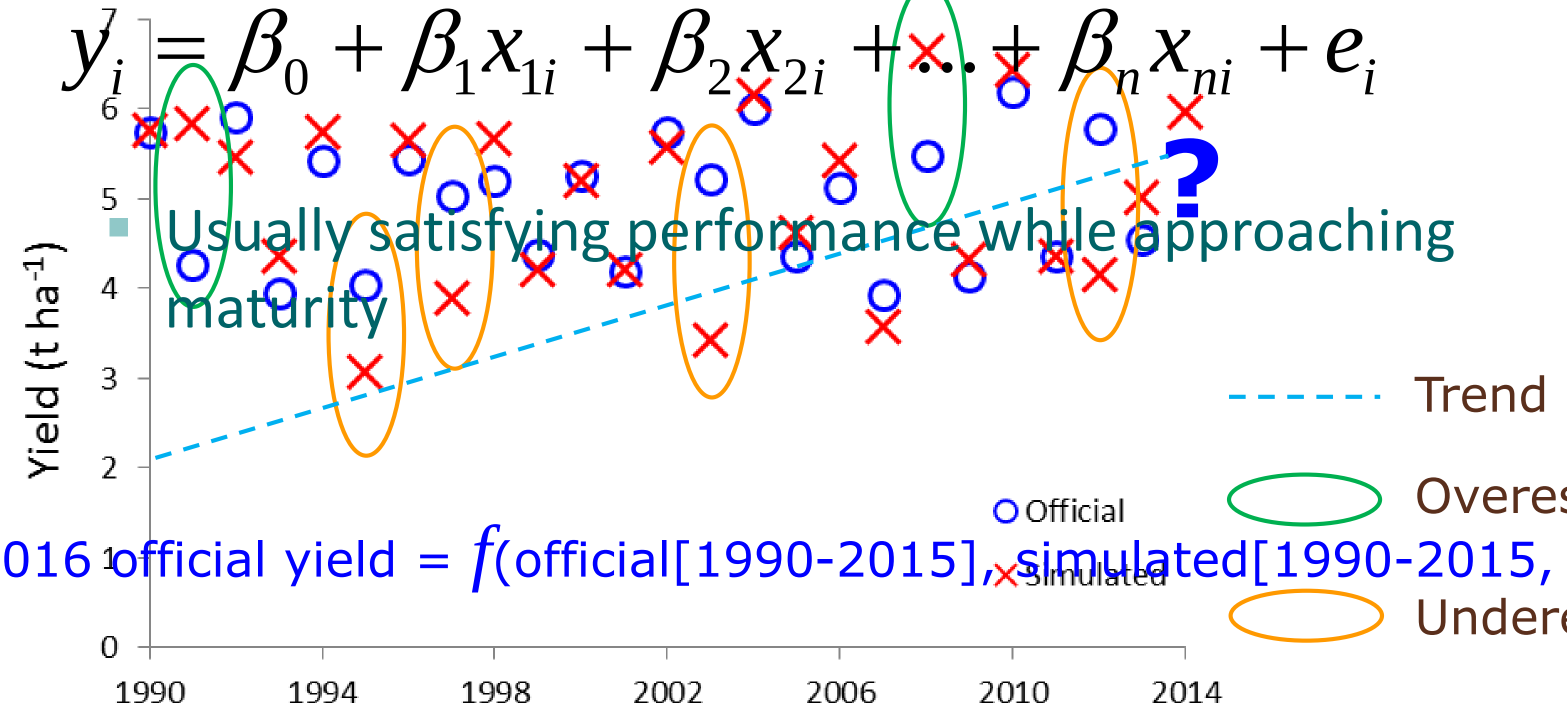
- Spatial level for analysis (on aggregated data):
  - NUTS0
- Post processing:
  - Something is not explicitly considered by the system
  - This generates uncertainty and specific system behaviour under specific conditions (assumption)
  - The same system behaviour will be reproduced under similar conditions
- “forecasts” unsupervised
- Cross-validation using the available historical series

General evaluation methodology

- De-trending historical yield statistics
- Multiple linear regression (stepwise, max. 4 regr.)

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_n x_{ni} + e_i$$

  - Usually satisfying performance while approaching maturity



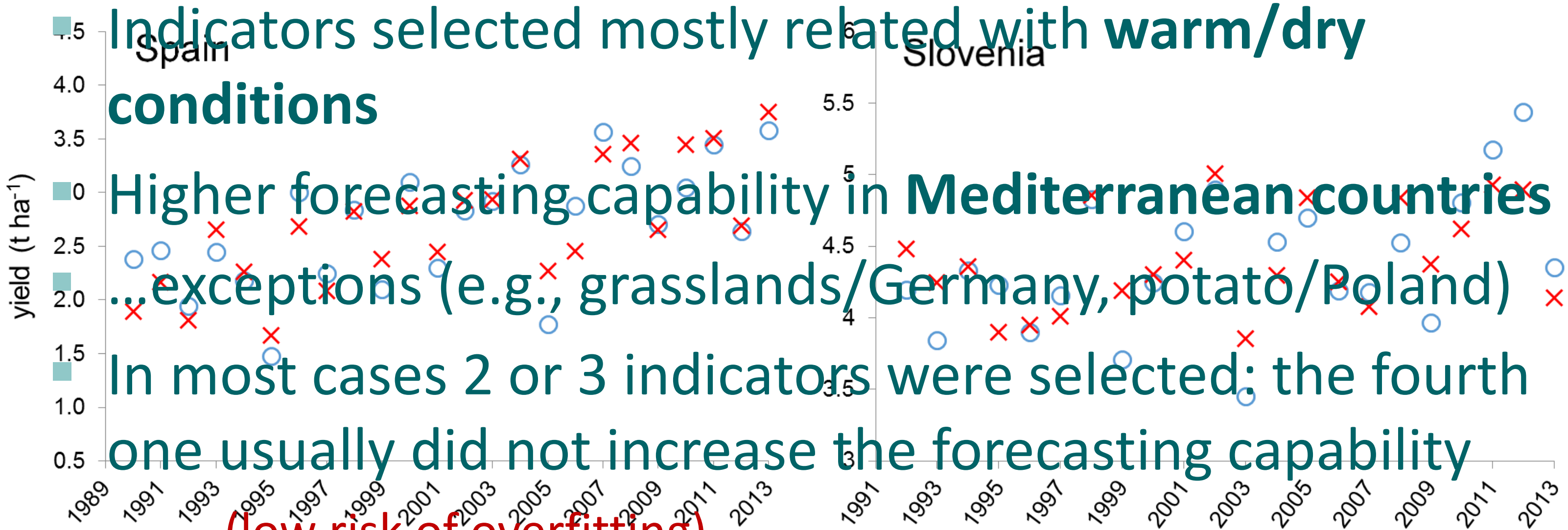
2016 official yield = f(official[1990-2015], simulated[1990-2015, 2016])

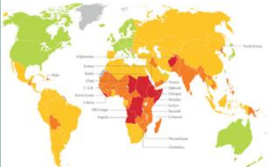
Agro-climatic indicators

- Selected agro-climatic indicators:
  - Heat
    - Tmaxcr (# days with Tmax > threshold)
  - Frost
    - Tmincr (# days with Tmin < threshold)
  - Drought
    - ARIDmean (mean Agricultural Reference Index [ARID; Woli et al., 2012] for drought)
    - ARIDcr (# days with ARID higher than a threshold)
    - Fu (Fu drought index; Fu, 1981)

Agro-climatic indicators

- Sample results: (wheat)
- Overall results:
  - Indicators selected mostly related with **warm/dry conditions**
  - Higher forecasting capability in **Mediterranean countries**
  - …exceptions (e.g., grasslands/Germany, potato/Poland)
  - In most cases 2 or 3 indicators were selected; the fourth one usually did not increase the forecasting capability
    (low risk of overfitting)
  - Best results achieved for:
    - Wheat and barley in Spain (82% and 85% of variability explained)
    - Sunflower in Bulgaria and sugar beet in Croatia (81% and 74%)



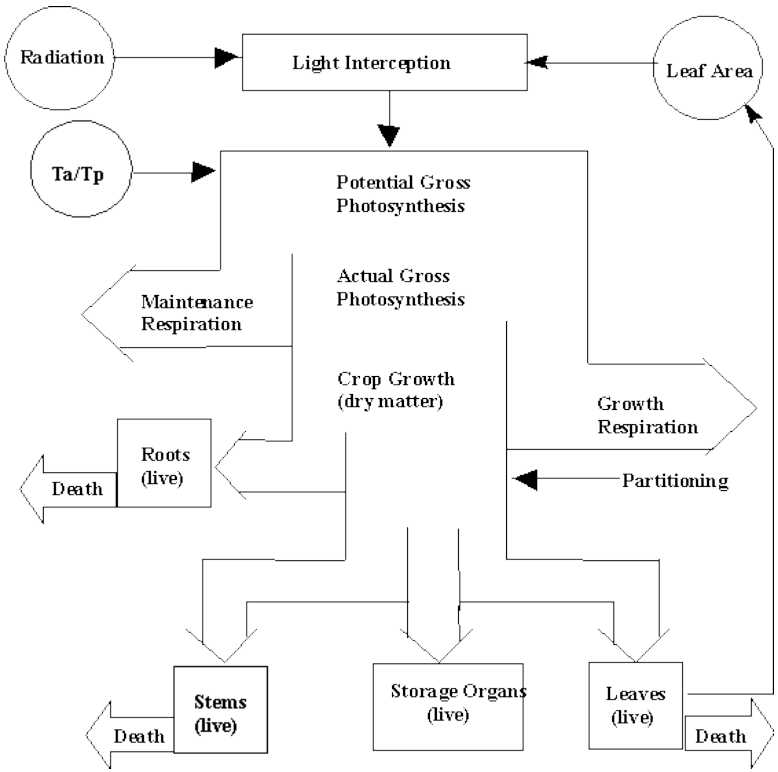




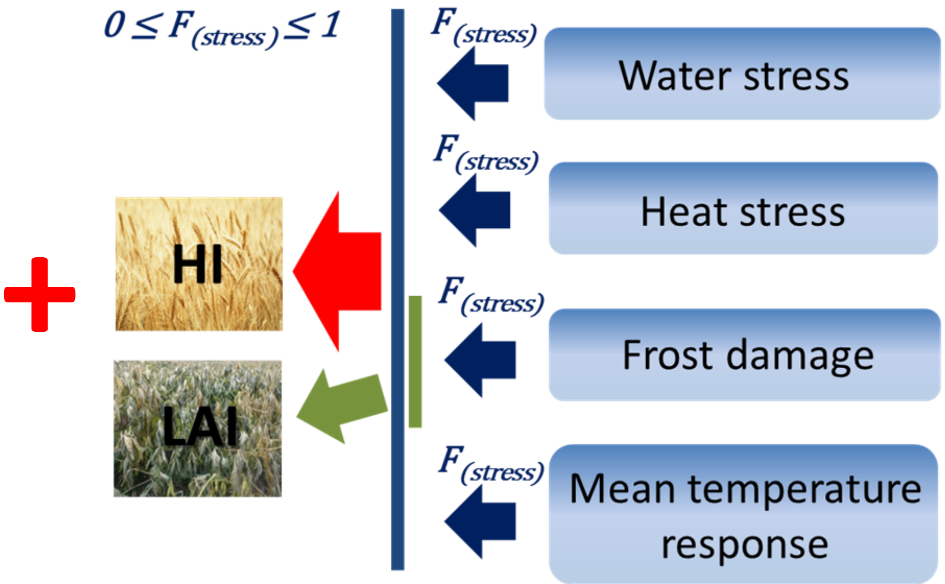

Process-based crop models

- Improved modelling solution include the approaches for the simulation of the impact of extreme weather events developed within the MODEXTREME project

CGMS WOFOST



MODEXTREME impact models



Process-based crop models

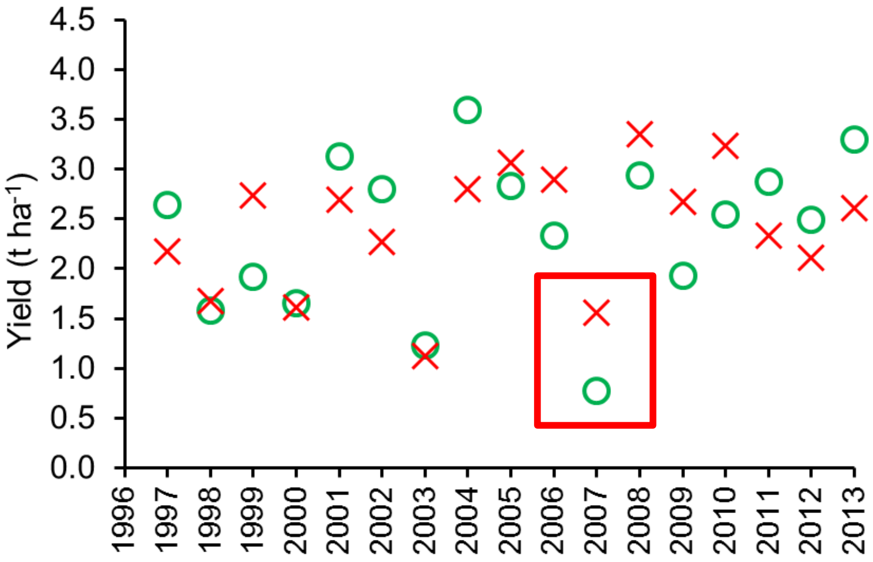
- The comparison between standard (CMGS) and improved (MODEXTREME) solutions allowed splitting results in five main categories:

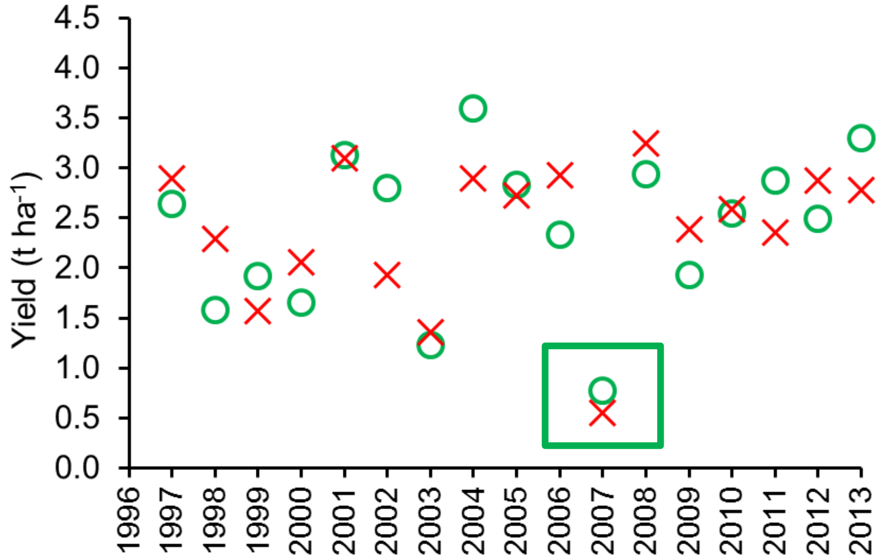
Category	R^2 of the standard modelling solution	MODEXTREME improvement for R^2	Examples
I	> 0.60	No improvement	Spring barley in Spain (forecast at the 14th 10-day period), maize in France (23rd 10-day period).
II	> 0.60	< 0.20	Maize in Germany (24th 10-day period), soft wheat in Spain (15th 10-day period)
III	< 0.60	No improvement	Potato in Poland, spring barley in Denmark
IV	< 0.60	< 0.20	Spring barley in UK (20th 10-day period), durum wheat in Spain (19th 10-day period)
V	< 0.60	> 0.20	Spring barley in Poland (20th 10-day period), soft wheat in Romania (12th 10-day period)






e.g., Durum Wheat– ES – maturity





Standard modelling solution

Indicators selected

(independent variables in the regression)

- LAI_{WL},
- WC,
- WR,
- DVS

R^2(TOT):0.40

Improved modelling solution

Indicators selected

(independent variables in the regression)

- LAI_{WL},
- ***fHEAT***,
- ***fCOLD***,
- **T_{MAX}CROP**

R^2(TOT):0.59

Process-based crop models

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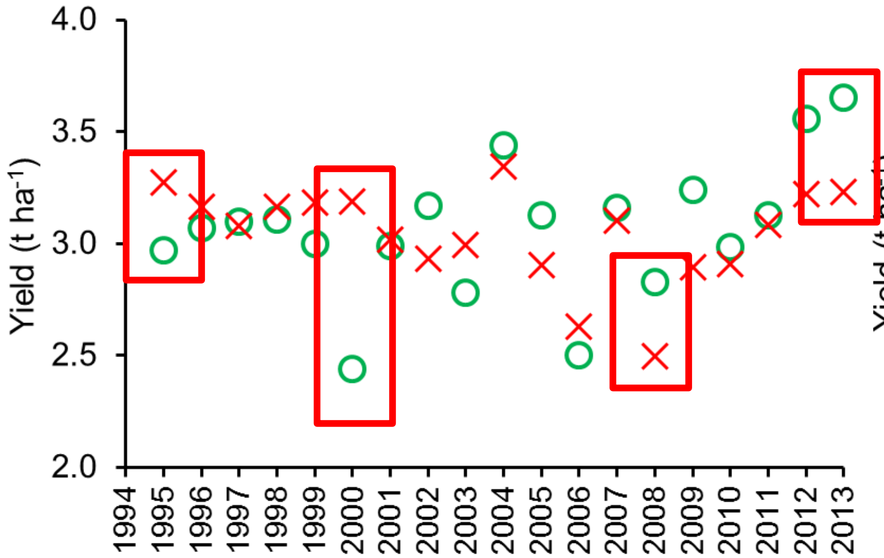
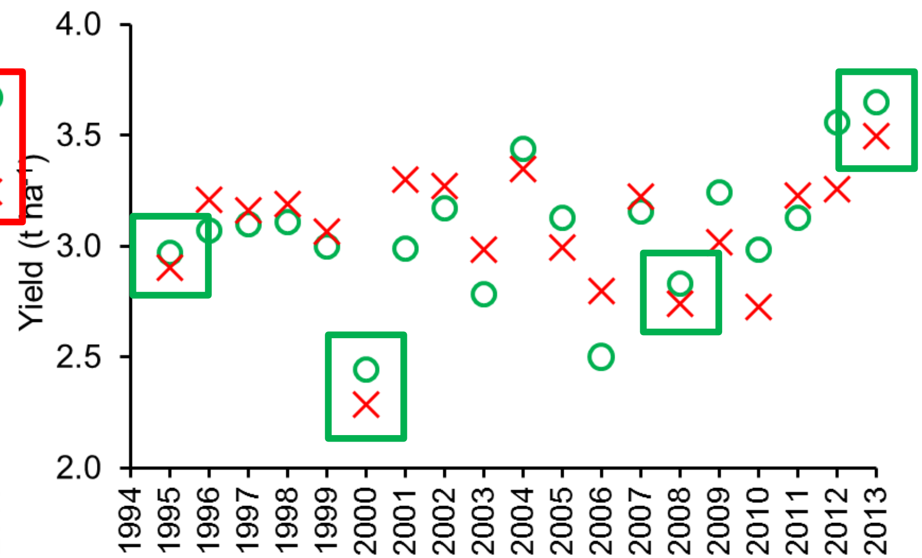
e.g., Spring Barley– PL – ripening





Standard modelling solution

Indicators selected

(independent variables in the regression)

- FSM,
- AGB_{WL},
- $YIELD_{WL}$,
- AGB_{Pot}

R^2(TOT):0.22

Improved modelling solution

Indicators selected

(independent variables in the regression)

- $LAI_{WL,}$
- DVS,
- $YIELD_{Pot,}$
- **AGB_{EE}**

R^2(TOT):0.66

Hybrid solutions

- **AGRO-CLIMATIC INDICATORS**
- **STATE VARIABLES**, simulated under **potential** and **water limited** conditions
- **SOIL-WATER-PLANT indicators**
- **STATE VARIABLES**, influenced by **extreme events**
- **RESPONSE FUNCTIONS** to extreme events
- **CROP TEMPERATURE**

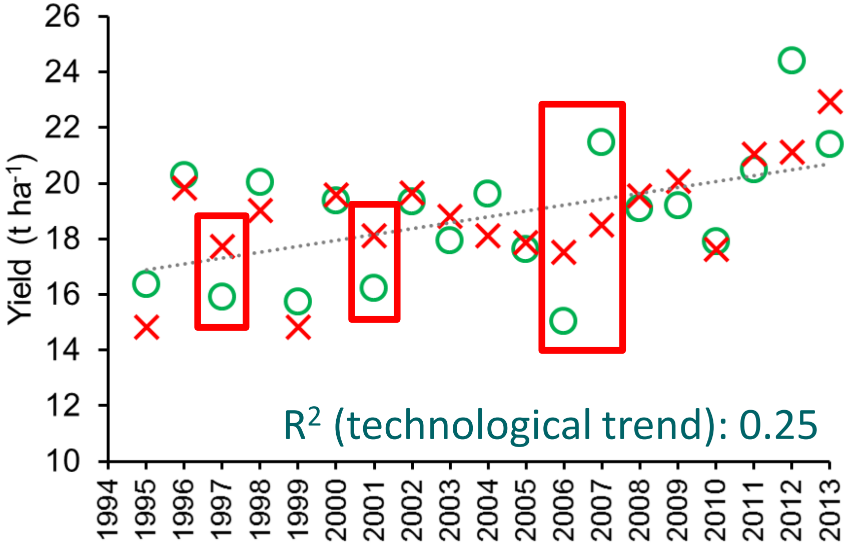
Variables	INDICATORS	STANDARD	IMPROVED	HYBRID
Tmaxcr	✓			✓
Tmincr	✓			✓
ARIDmean	✓			✓
ARIDcr	✓			✓
Fu	✓			✓
AGBPot		✓	✓	✓
AGBWL		✓	✓	✓
YIELDPot		✓	✓	✓
YIELDWL		✓	✓	✓
LAIPot		✓	✓	✓
LAIWL		✓	✓	✓
DVS		✓	✓	✓
WC		✓	✓	✓
WR		✓	✓	✓
FSM		✓	✓	✓
AGBEE			✓	✓
YIELDEE			✓	✓
LAIEE			✓	✓
fHEAT			✓	✓
TMAXCrop			✓	✓
fCOLD			✓	✓
TMINCrop			✓	✓
fWS			✓	✓






e.g., Potato – PL – maturity

Improved MODEXTREME system



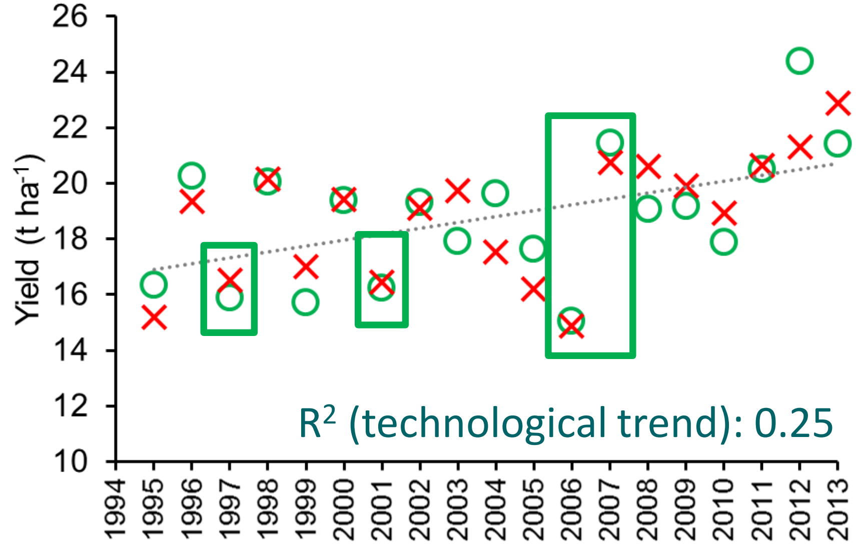
Regressors

TMINCrop

AGB_{Pot}

R^2: 0.57

Hybrid system



Regressors

ARIDcr

T_{MIN}Crop

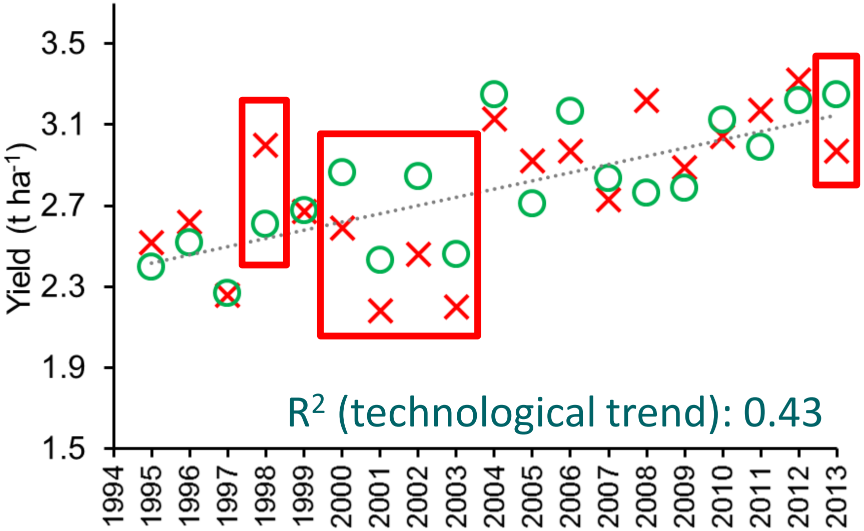
$YIELD_{Pot,}$

$YIELD_{EE}$

R^2: 0.71

e.g., Durum wheat – IT – ripening

Improved MODEXTREME system



Regressors

FSM

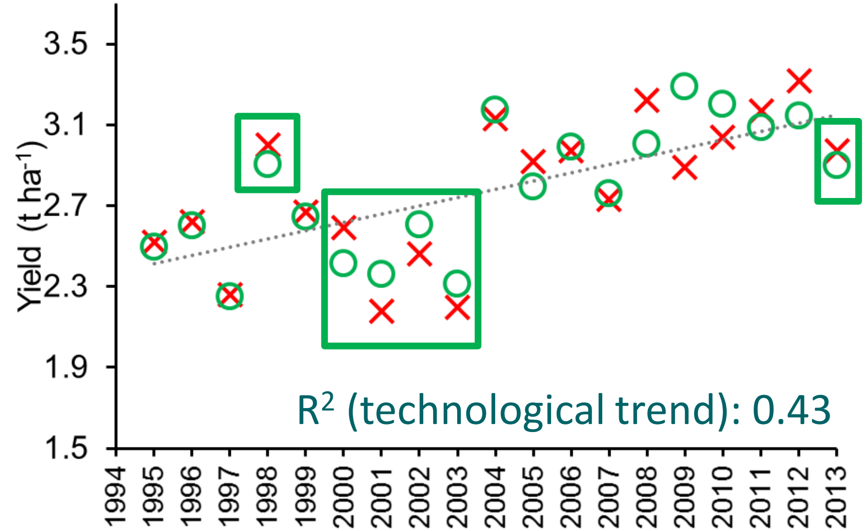
LAI_{Pot}

DVS

AGB_{EE}

R^2: 0.57

Hybrid system



Regressors

FSM

$ARID_{cr}$

$TMAX_{cr}$

TMAXCrop

R^2: 0.82

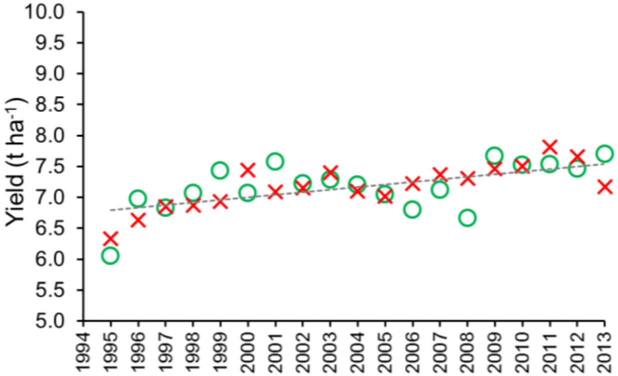





Rice (e.g., Spain – maturity)

MARS

Adm. level: NUTS0 (**Spain**)
Crop: **rice**



R^2 = 0.40
R^2 (technological trend) = 0.33

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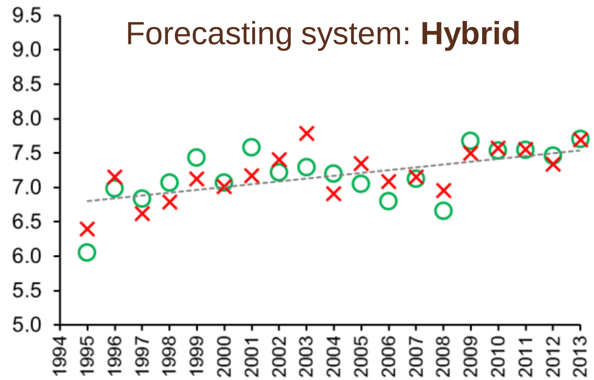
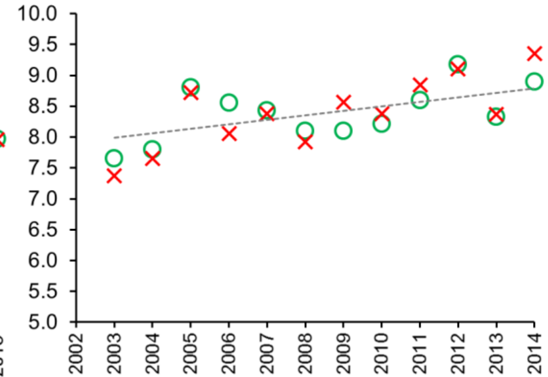
Adm. level: NUTS0 (**Spain**)
Crop: **rice**



R^2 = 0.61
R^2 (technological trend) = 0.33

ERMES
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

Adm. level: NUTS2 (**Valencia**)
Crop: **rice – *Japonica* type**



R^2 = 0.74
R^2 (technological trend) = 0.33

e.g., Maize workflows

ID	10-day period	Selected system
France	19th	MODEXTREME system
	23th	CGMS system
	28th	HYBRID system
Romany	19th	MODEXTREME system
	23th	MODEXTREME system
	28th	MODEXTREME system
Italy	19th	MODEXTREME system
	23th	HYBRID system
	28th	MODEXTREME system
Hungary	20th	MODEXTREME system
	24th	MODEXTREME system
	29th	CGMS system
Spain	19th	HYBRID system
	23th	MODEXTREME system
	28th	HYBRID system
Germany	20th	MODEXTREME system
	24th	MODEXTREME system
	29th	MODEXTREME system

e.g., Soft wheat workflows

ID	10-day period	Selected system
France	12th	MODEXTREME system
	15th	MODEXTREME system
	19th	MODEXTREME system
Germany	15th	MODEXTREME system
	19th	MODEXTREME system
	22th	HYBRID system
Italy	12th	MODEXTREME system
	15th	HYBRID system
	19th	HYBRID system
Romany	12th	MODEXTREME system
	15th	HYBRID system
	19th	MODEXTREME system
Spain	12th	MODEXTREME system
	15th	HYBRID system
	19th	HYBRID system

e.g., Potato workflows

ID	10-day period	Selected system
Poland	16th	AGRO-CLIMATIC system
	21th	HYBRID system
	26th	HYBRID system
Germany	16th	AGRO-CLIMATIC system
	21th	HYBRID system
	26th	HYBRID system
Netherland	16th	HYBRID system
	21th	MODEXTREME system
	26th	HYBRID system
France	14th	MODEXTREME system
	19th	MODEXTREME system
	25th	HYBRID system
United Kingdom	16th	HYBRID system
	21th	HYBRID system
	26th	HYBRID system

Conclusions

- The inclusion of **MODEXTREME impact models** led to **improve** the forecasting reliability in **70% of the combinations** crop × country × forecasting moment (within the crop cycle).
- The integrated use of the four forecasting systems (**hybrid**) allowed to **improve** CGMS performances in **87% of the combinations** crop × country × forecasting moment.
- **Most of the improvement** in the forecasting reliability was due to the **MODEXTREME impact models** (improved solutions).
- The addition of **agro-climatic indicators** to those provided by the improved solutions led to a **slight improvement** of forecasting performance in **24% of the cases**.
- **Results for rice** fully satisfactory only in **Spain and Italy** (despite the overall improvement compared to the CGMS system)… The **EU-FP7 ERMES project** could be a solution.

Acknowledgement

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