modextreme

agriculture facing extreme climatic events

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Yield forecast at EU level

Valentina Pagani, Tommaso Guarneri, Roberto Confalonieri

(Cassandra lab, University of Milan)

Tommy Klein, Pierluigi Calanca

(WBF-Agroscope)

Cassandra models for change

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WP 5 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

Introduction

- There's an **increasing demand** for crop yield forecasting system 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

Introduction

- In the last years, a variety of forecasting systems were proposed, based on:
  - Field surveys
  - Crop models
  - Remote sensing
  - Integrated approaches
- However, in specific contexts where **yield fluctuations** are driven by **few main factors**, systems based on **agro-climatic indicators** proved their reliability (e.g. Balaghi et al., 2012)

Introduction

- Objectives of Task 5.2:
  - Evaluate the potential of forecasting systems based on **temperature** and **drought indicators** for **winter and summer crops** and for **grasslands** in Europe
  - Identify **combinations crop × country** where systems based on agro-climatic indicators present sufficient reliability

Methods

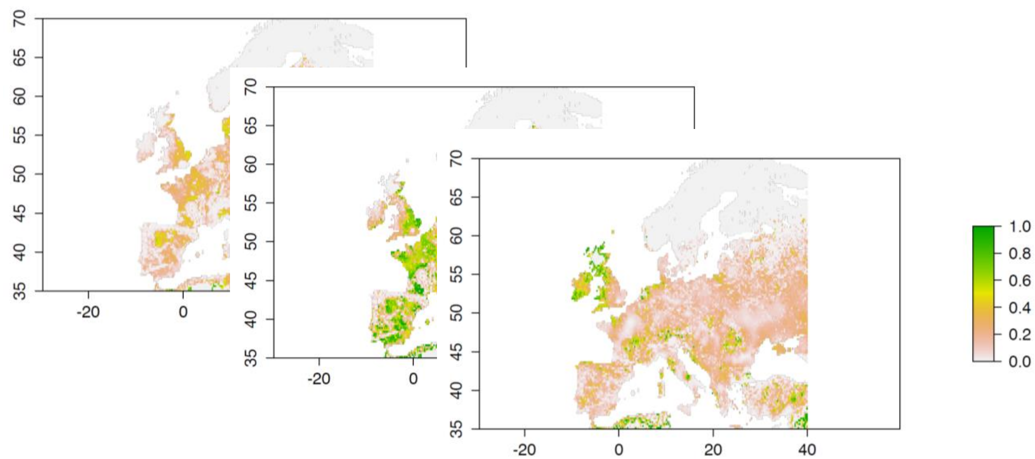
- Agro-climatic indicators (WP1):
  - Heat
    - Tmaxcr (# days with Tmax > threshold)
  - Frost
    - Tmincr (# days with Tmin < threshold)
  - Drought
    - ARIDmean (mean Agricultural Reference Index [ARID; Woli et al., 2012] for drought) $ARID = 1 - \frac{T_a}{T_p}$
    - ARIDcr (# days with ARID higher than a threshold)
    - Fu (Fu drought index; Fu, 1981) $FU = -\frac{\sum P}{\sum ET_0} + \left[1 + \left(\frac{\sum P}{\sum ET_0}\right)^w\right]^{(1/w)}$

Methods

- Crops (CGMS):
  - Maize
  - Rice
  - Sunflower
  - Potatoes
  - Sugar beet
  - Wheat
  - Barley
  - Rye
  - Triticale
  - Rapeseed
  - Grassland
- Countries:
  - Whole Europe
- Time series:
  - 1990-2013 (3 forecasting events per season)

Methods

- Input data:
  - Weather data: E-OBS database (Haylock et al., 2008)
  - Official yield statistics: FAOSTAT database
  - Flowering-maturity: according to the MARS crop calendars
  - Crop masks: Monfreda et al. (2008)
    - cereals
    - other crops
    - grasslands

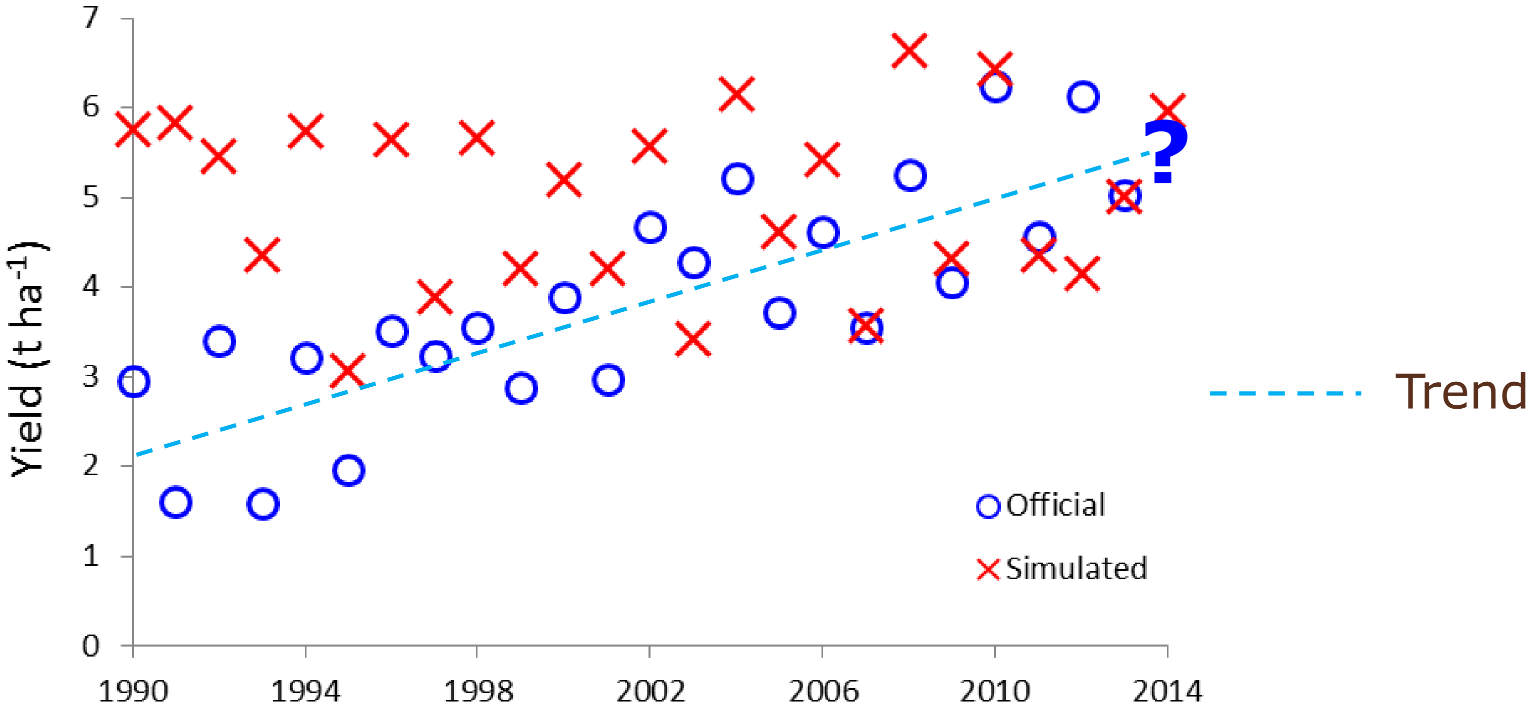


Methods

- Spatial level for analysis:
  - NUTS0
- Post processing (JRC-MARS operational chain):
  - Something is **not explicitly considered** by the system
  - This generates **uncertainty** and **specific system behaviours** under specific conditions (assumption)
  - The **same behaviour** will be reproduced **under similar conditions**

Methods

- De-trending historical yield statistics



Methods

- De-trending historical yield statistics
  - Are there discontinuities in the series of official yields?

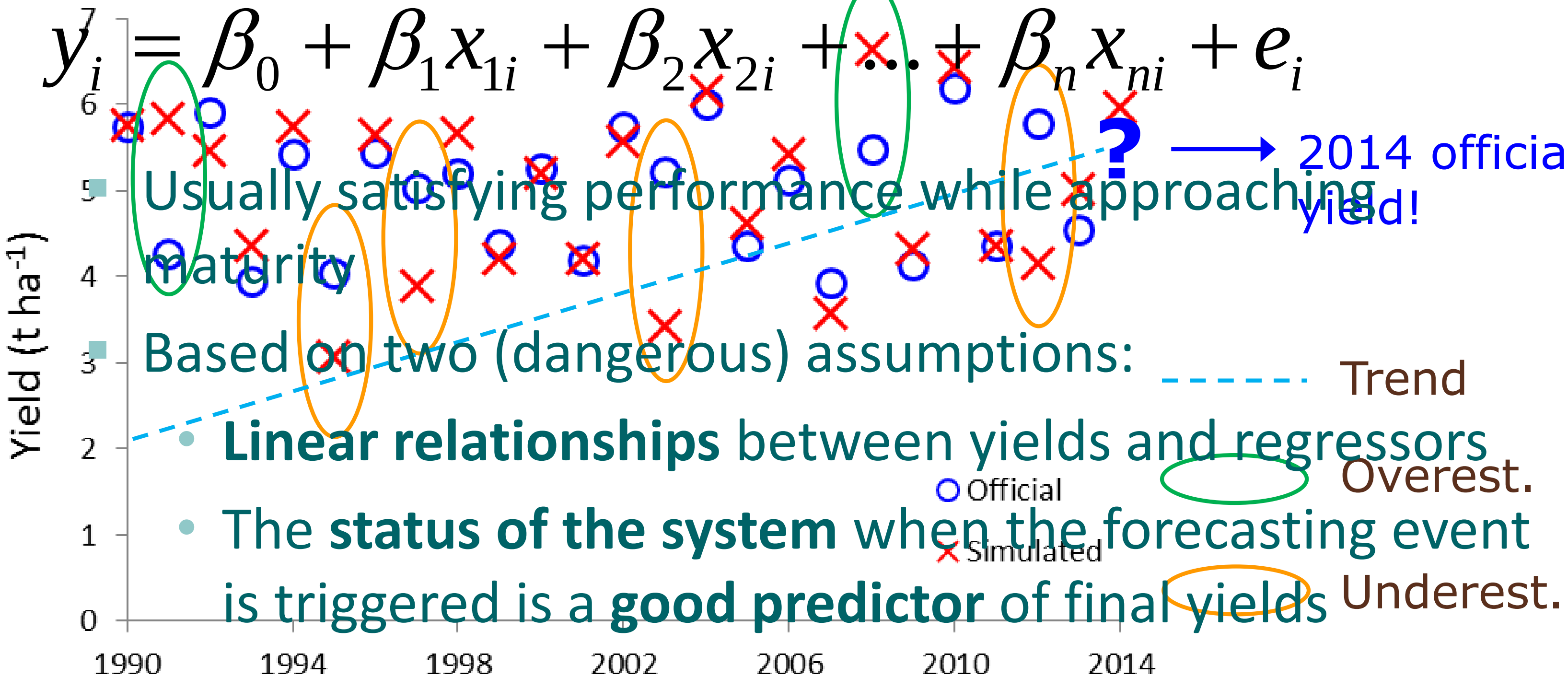
    (e.g. the dissolution of the Soviet Union let to the abandonment of irrigation systems in many areas)
  - No, but there’s a trend
    - Technological (e.g. new varieties, machines)
    - Due to something the system should capture (e.g. climate change)
  - The **analyst** should understand **case-by-case** how the trend should be managed
  - If due to something that cannot be reproduced by the system, it should be eliminated

Methods

- Multiple linear regression

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

- Usually satisfying performance while approaching maturity
- Based on two (dangerous) assumptions:
  - **Linear relationships** between yields and regressors
  - The **status of the system** when the forecasting event is triggered is a **good predictor** of final yields



2014 official yield = *f*(official[1990-2013], simulated[1990-2013, 2014])

Methods

- Analysis performed in **two steps**:
  - **Screening** all the combinations crop × country × forecasting moment
  - **Percentage of variance** in yields explained by:
    - Trend
    - Regression model
  - **Complete cross-validation** where
    - Regression model was able to explain "*in a reasonable way*" the **inter-annual variability** in yields
  - Completely unsupervised

Results

- Sample results for the regression models
- General considerations:
  - **Forecasting capability** of agro-climatic indicators was **higher in central and southern Europe**
  - **Exceptions** were grasslands in Germany and potatoes in Poland
  - **Indicators selected** by the **step-wise** procedure were mostly related with **warm/dry conditions**
    - Often Mediterranean countries
    - Dry summers and mild/rainy winters

Maize

Country	Period	Trend	27th ten-day period Model	27th ten-day period Total	24th ten-day period Model	24th ten-day period Total	20th ten-day period Model	20th ten-day period Total
Austria	1990-2013	0.72	0.18	0.9	0.18	0.9	0.05	0.77
Belgium	2000-2013	0	0.74	0.74	0.76	0.76	0.7	0.7
Bulgaria	1990-2013	0	0.49	0.49	0.58	0.58	0.49	0.49
Croatia	**1992-2013**	**0.25**	0.6	0.85	0.61	0.86	**0.64**	**0.89**
Czech R.	1993-2013	0.49	0.22	0.71	0.23	0.72	0.21	0.7
France	1990-2013	0.51	0.37	0.88	0.38	0.89	0.16	0.67
Greece	1990-2013	0.5	0.17	0.67	0.15	0.65	0.13	0.63
Germany	1990-2013	0.71	0.21	0.92	0.2	0.91	0.13	0.84
Hungary	1990-2013	0	0.57	0.57	0.69	0.69	0.41	0.41
Italy	**1990-2013**	**0.38**	**0.43**	**0.81**	**0.44**	**0.82**	0.44	0.82
Netherlands	1992-2013	0.54	0.07	0.61	0.06	0.6	0.08	0.62
Poland	1990-2013	0.48	0.32	0.8	0.34	0.82	0.39	0.87
Portugal	1990-2013	0.78	0.07	0.85	0.06	0.84	0.05	0.83
Romania	1990-2013	0	0.53	0.53	0.67	0.67	0.45	0.45
Slovakia	1993-2013	0	0.44	0.44	0.58	0.58	0.6	0.6
Slovenia	1992-2013	0.46	0.38	0.84	0.38	0.84	0.2	0.66
Spain	1990-2013	0.88	0.02	0.9	0.03	0.91	0.01	0.89

Wheat

Country	Period	Trend	15th 10-day period Model	15th 10-day period Total	13th 10-day period Model	13th 10-day period Total	11th 10-day period Model	11th 10-day period Total
Austria								
Belgium								
Bulgaria								
Croatia								
Denmark								
Czech R.								
Estonia								
Finland								
France								
Greece								
Germany								
Hungary								
Ireland								
Italy								
Latvia								
Lithuania								
Netherlands								
Poland								
Portugal								
Romania	1990-2013	0	0.34	0.34	0.27	0.27	0.09	0.09
Slovakia	1993-2013	0	0.56	0.56	0.44	0.44	0.05	0.05
Slovenia	**1992-2013**	**0.24**	**0.57**	**0.81**	0.24	0.48	0.12	0.36
Spain	**1990-2013**	**0.31**	**0.58**	**0.89**	0.5	0.81	0.37	0.68
Sweden	1990-2013	0	0.18	0.18	0.21	0.21	0.29	0.29
United Kingdom	1990-2013	0.38	0.05	0.43	0.05	0.43	0.01	0.39

Results

- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - In general:
  - **Good results** achieved for each of the 11 crops **in one or two countries**
  - **Exception was rice**, for which no satisfactory results were achieved
    - Flooded
    - Macrothermal crop originated in the tropics

    No conditions characterized by **heat and drought** (differently from other crops)

Results

- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - **ARIDcr** (# days with ARID higher than a threshold) and **Tmaxcr** (# days with Tmax > threshold) were the indicators **selected more frequently** as regressors
  - **No relevant impact** of **low temperatures**: Tmincr (# days with Tmin < threshold) was rarely selected
  - In most cases **2 or 3 indicators were selected**: the fourth one usually did not increase the forecasting capability

    (low risk of overfitting!)

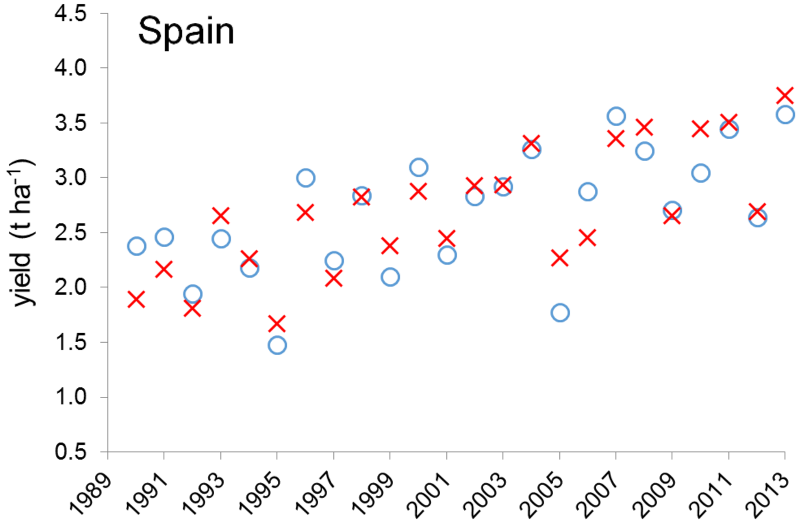
	Crop	Country	Regression model	RRMSE	EF	CRM	R^2
Winter crops	Wheat	Spain	$ARID_{mean}$, $ARID_{cr}$, T_{maxcr}	0.24	0.80	0.00	0.82
		Slovenia	$ARID_{mean}$, $ARID_{cr}$, Fu, T_{mincr}	6.19	0.66	-0.01	0.67
	Barley	Italy	$ARID_{cr}$, Fu, T_{maxcr}, T_{mincr}	3.42	0.48	0.00	0.58
		Spain	$ARID_{cr}$, T_{maxcr}	9.84	0.84	0.01	0.85
	Rye	Spain	$ARID_{cr}$, T_{maxcr}, T_{mincr}	0.21	0.76	0.00	0.76
	Triticale	Romania	$ARID_{cr}$, Fu, T_{maxcr}	15.96	0.07	0.00	0.33
	Rapeseed	Romania	$ARID_{mean}$, T_{maxcr}	20.52	0.65	-0.03	0.66
Summer crops	Maize	Italy	$ARID_{mean}$, T_{maxcr}, T_{mincr}	4.86	0.62	0.00	0.65
		Croatia	$ARID_{mean}$, T_{maxcr}	11.35	0.68	0.00	0.71
	Sunflower	Bulgaria	$ARID_{mean}$, Fu, T_{maxcr}	12.97	0.80	0.01	0.81
		Italy	T_{maxcr}, T_{mincr}	6.87	0.43	0.00	0.45
	Potato	Romania	$ARID_{cr}$, Fu, T_{maxcr}	9.82	0.52	-0.01	0.53
		Poland	$ARID_{mean}$, $ARID_{cr}$, T_{maxcr}	8.04	0.66	0.00	0.68
	Sugar beet	Italy	$ARID_{cr}$, T_{mincr}	7.02	0.69	0.00	0.69
		Croatia	$ARID_{cr}$, Fu	10.78	0.73	0.00	0.74
	Mown Grasslands	Germany	$ARID_{mean}$, $ARID_{cr}$, T_{mincr}	4.49	0.47	0.00	0.59

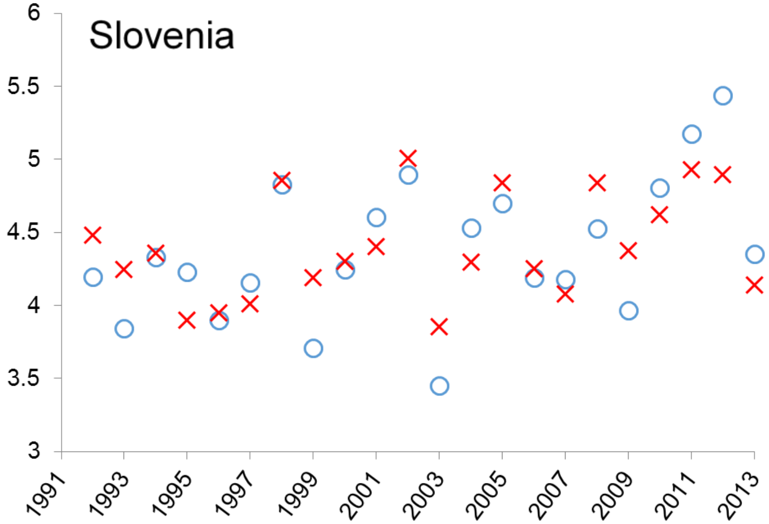
Results

- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - **Best results** achieved for **wheat**, **barley** and **rye** in **Spain** (82%, 85% and 76% of yields variability explained)
  - Good results also for **sunflower in Bulgaria** and **sugar beet in Croatia** (81% and 74%), the latter mainly because of technological innovations
  - **Poor results** for **triticale in Romania**, mainly because of the **short historical series** (regression model not robust)

Results

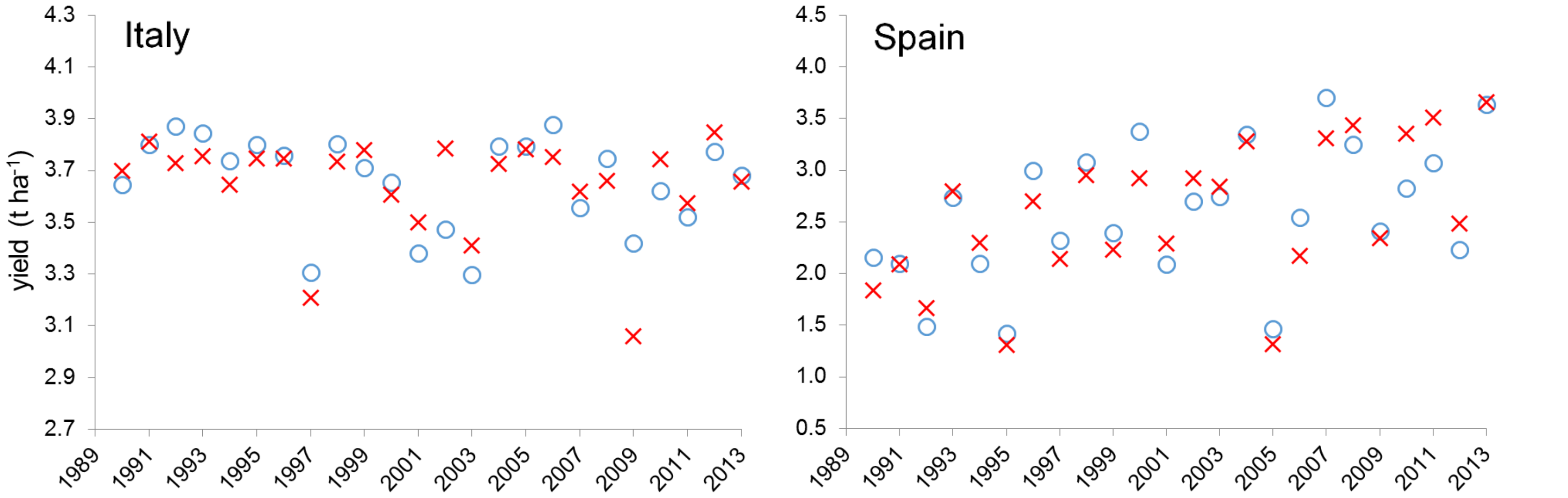
- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - Examples for:
    - Wheat





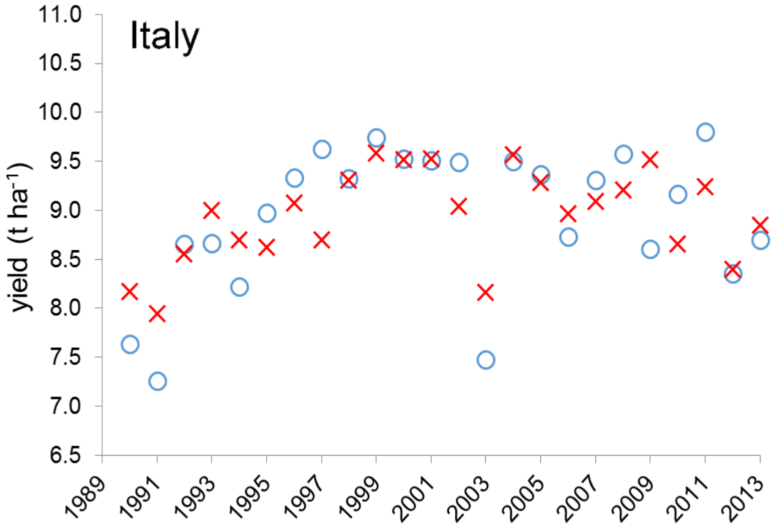
Results

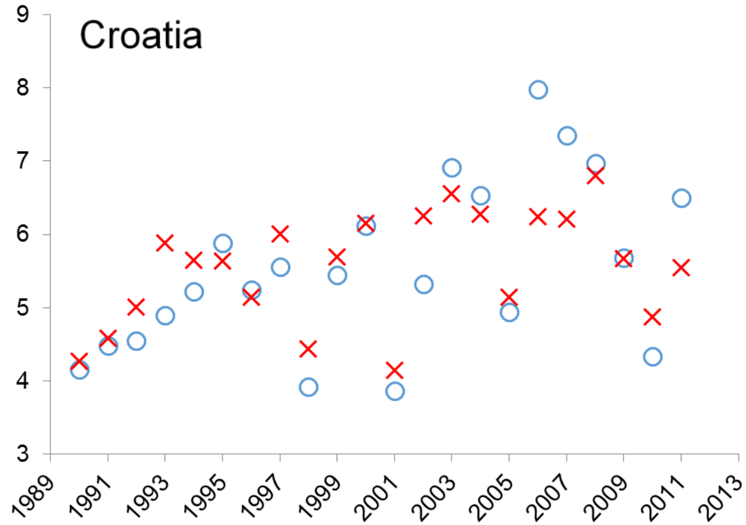
- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - Examples for:
    - Barley



Results

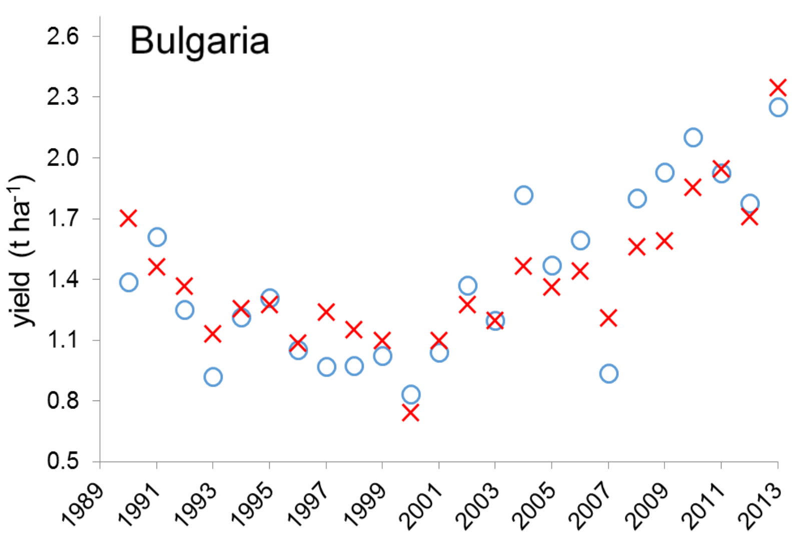
- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - Examples for:
    - Maize

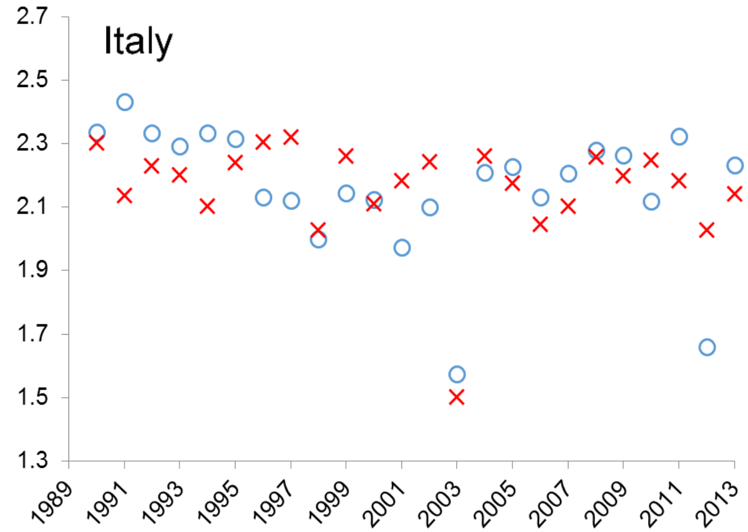




Results

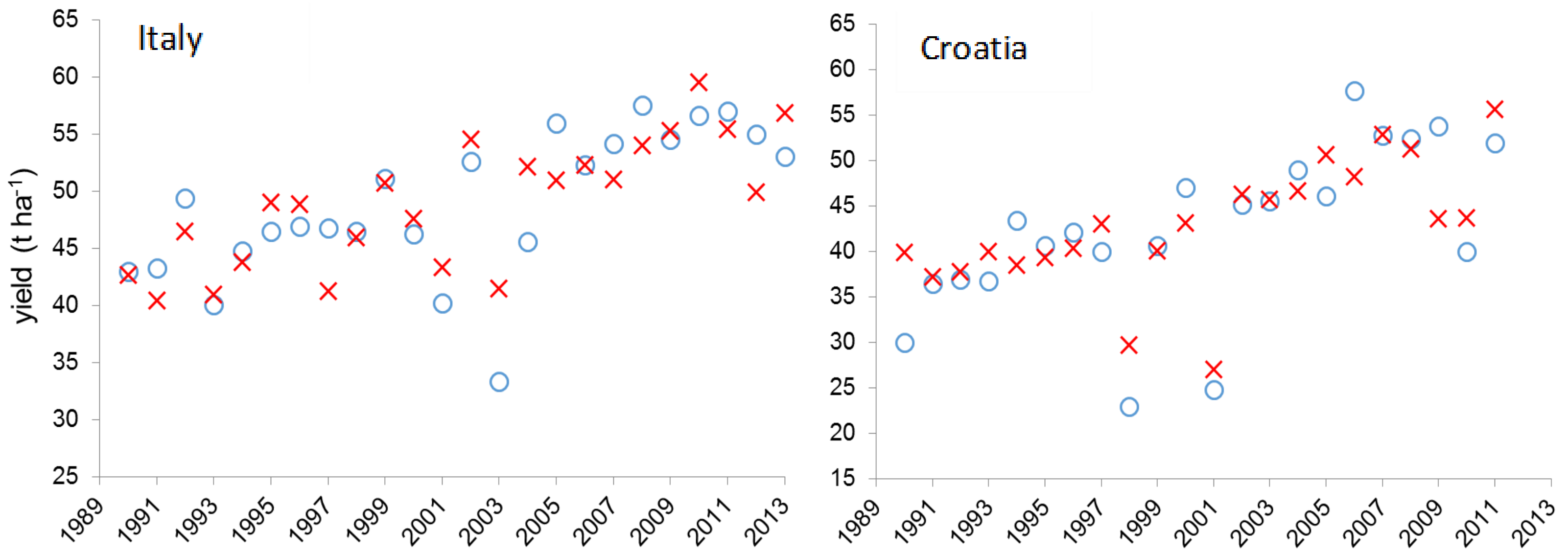
- Results for the **step 2** (**complete cross validation** on combinations crop × country **screened**)
  - Examples for:
    - Sunflower





Results

- Results for the **step 2 (complete cross validation** on combinations crop × country **screened)**
  - Examples for:
    - Sugar beet



Conclusions

- **Good results** in countries where **production is mainly driven** by the occurrence of **extreme conditions**, especially **drought** and **heat**
- It will be interesting to test **hybrid approaches** (dynamic models + agro-climatic indicators)
- Ideas for the future:
  - Perform the **test at NUTS2** (or NUTS3…) level
    (**Extreme events can be local**)
  - **Crop masks changing** during the time series (?)

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