European Commission

Seasonal forecasting in agriculture: challenges and opportunities

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Joint Research Centre
European Commission

Food Security
Monitoring Agricultural Resources

Joint Research Centre

Crop monitoring and yield forecasting

- **Monitoring Agricultural ResourceS (MARS)**
  - Agricultural Monitoring
  - Crop Yield Forecasting
  - Global Food Security
  - Agricultural Biodiversity
  - Rural Development
  - Climate Change
  - Earth Observation


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Monitoring Agricultural ResourceS

Monitoring Agricultural ResourceS (MARS)

The JRC's monitoring of agriculture using remote sensing started in 1988, initially designed to apply emerging space technologies for providing independent and timely information on crop areas and yields. Since 1993, this activity has contributed towards a more effective and efficient management of the common agricultural policy (CAP) through the provision of a broader range of technical support services to DG Agriculture and Member-State Administrations. Since 2000, the expertise in crop yields has been applied outside the EU. Services have been developed to support EU aid and assistance policies and provide building blocks for a European capability for global agricultural monitoring and food security assessment.

The JRC develops methods, tools and systems for use within agricultural monitoring activities applied to Europe, sub-Saharan Africa and other areas of the world. **Crop yield forecasting** is undertaken to provide monthly bulletins forecasting crop yields to support the EU's Common Agriculture Policy (CAP). Providing early warning of crop shortages or failure provides rapid information for EU development aid activities to support food insecure countries, as part of the JRC work on **global food security**. Within the CAP, techniques and guidance are continually being refined for the standardized measurement of field areas, identification of crop types, geo-location of landscape features and assessment of environmental impacts. Such techniques for **agricultural monitoring** are a key part of the Integrated Agricultural Control System (IACS) which is at the

Related Publications

Prediction of drought-induced reduction of agricultural productivity in Chile from MODIS, rainfall estimates, and climate oscillation indices

New sensors benchmark report on KOMPSAT-3A: Geometric benchmarking over Maussane test site for CAP purposes

Development of a national and sub-national crop calendars data set compatible with remote sensing derived land surface phenology

Anomaly hot Spots of Agricultural Production

New sensors benchmark report on PlanetScope: Geometric benchmarking test for Common Agricultural Policy (CAP) purposes

More >

Updates

OCT 18 2018 Forecasting wheat yields under extreme weather conditions

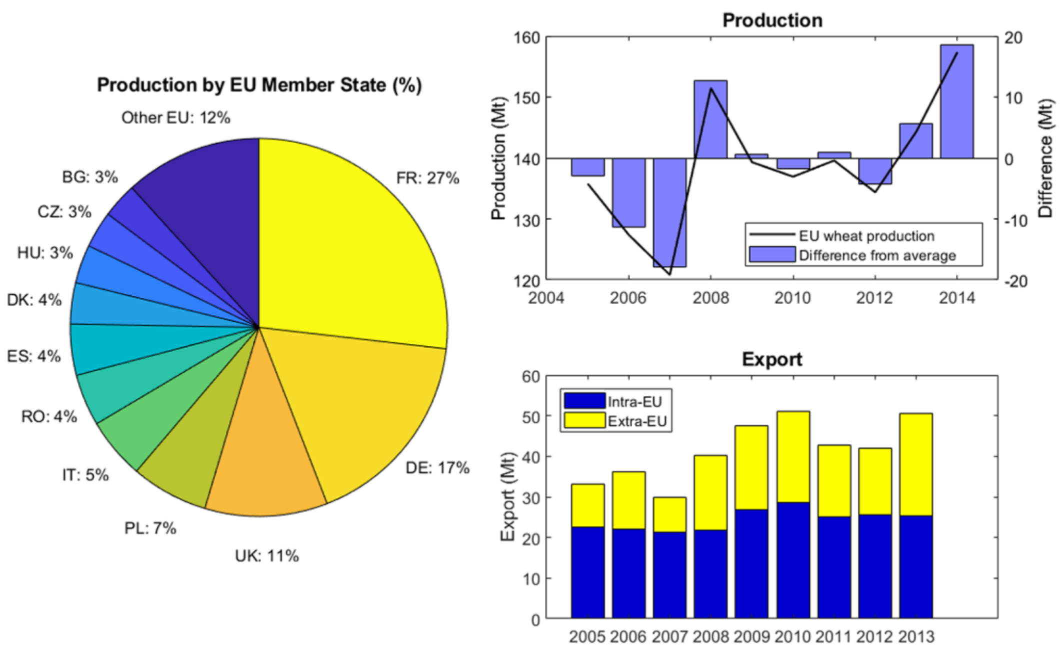
https://ec.europa.eu/jrc/en/mars/

Crop monitoring and yield forecasting

- **Global and regional perspectives**
  - minimise socio-economic impacts of crop losses (early warning/prevention)
  - guarantee humanitarian food assistance (emergency responses)
  - improve crop marketing and planning (increase market transparency, maintain market stability)

- **Local perspective (farmers)**:
  - crop production planning
  - production input planning
  - crop field operations planning
  - crop field investment decissions

Crop monitoring and yield forecasting



Production and export of common wheat, durum wheat and spelt by the EU (van der Velde et al., 2018)

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Crop monitoring and yield forecasting

- **Need to forecast crop yields:**
  - Information on expected EU crop production levels is of direct relevance not only to EU but also to countries in North Africa and the Middle East
  - Impacts across large crop production areas due to increasingly variable or extreme weather and pest outbreaks can create knock-on effects that may affect food prices and availability elsewhere.
  - Estimates of crop yield prior harvesting allow producers, exporters, importers, traders, and companies to make informed decisions across sectors covering raw materials, manufacturing, and sales and services
  - Commodity markets are becoming more and more interconnected (mitigate market volatility)

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Crop monitoring and yield forecasting

Monitoring Agricultural ResourceS (MARS)

- The JRC's monitoring of agriculture using remote sensing started in 1988

- It has contributed towards a more effective and efficient management of the common agricultural policy (CAP)
  - Independent, timely, scientific and traceable crop yield forecast for all MS and EU neighbouring countries

  - Assessment of climatic conditions and potential impacts of particular weather events

  - Monitoring of crop conditions and forecasting in third countries

Crop monitoring and yield forecasting

- **Large-scale monitoring and crop yield forecasting relies on:**
  - regionalized analyses of cultivated areas, crop type distribution and crop condition based on near-real-time satellite imagery merged with available in-situ observations
  - meteorological monitoring and mid-term forecasts based on observation networks and model outputs
  - regionalized knowledge of agricultural systems and sensitivities to meteorological conditions

Crop monitoring and yield forecasting

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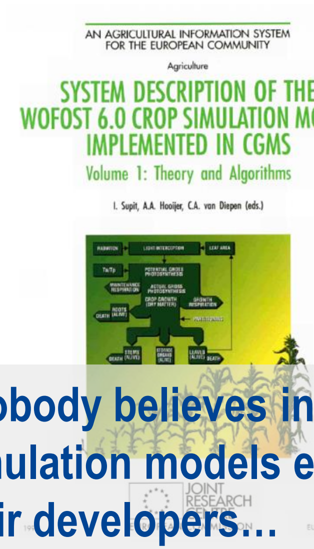
Crop model



"Nobody believes in simulation models except their developers…

Satellite data

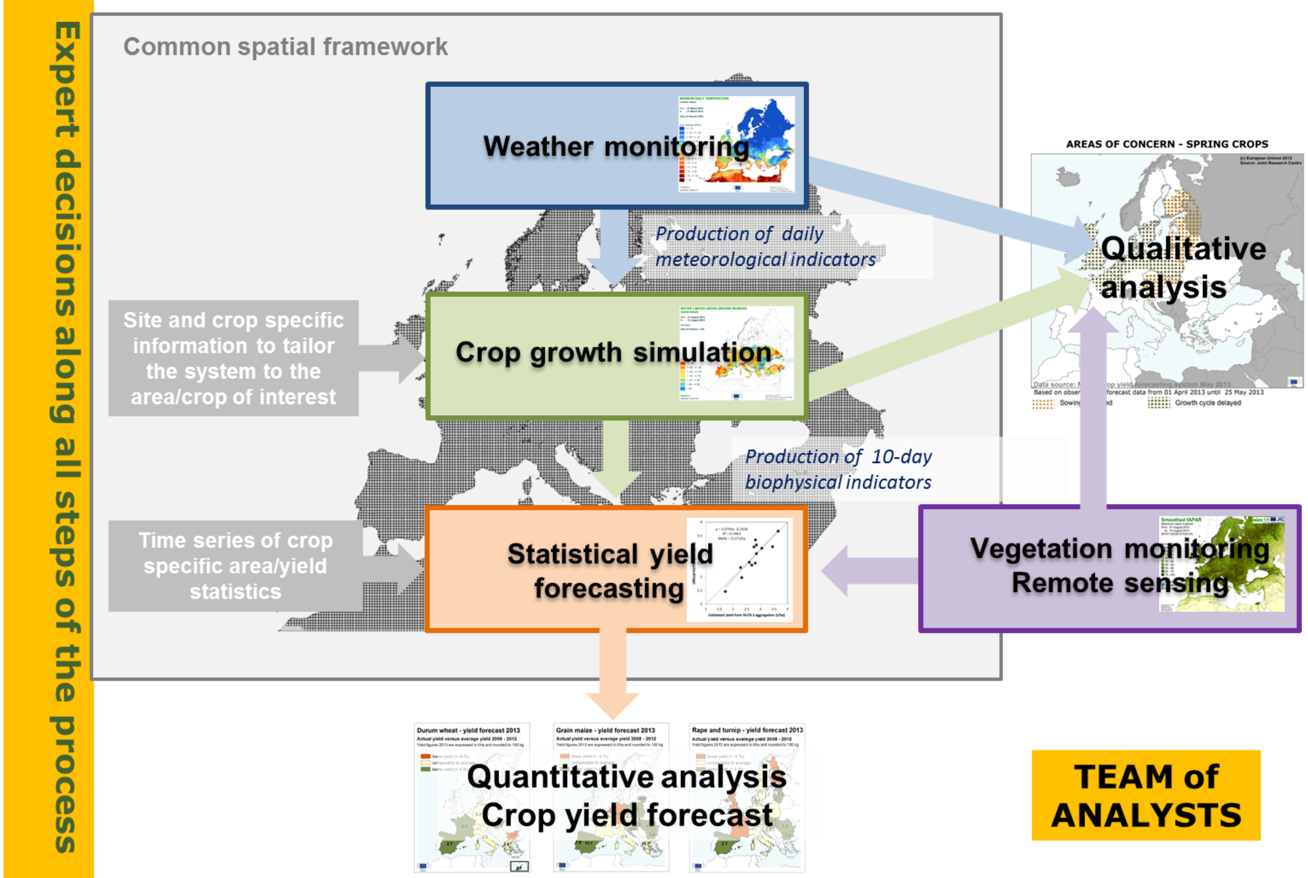
Everybody believes in experimental data except who collected them"

Gaylon S. Campbell

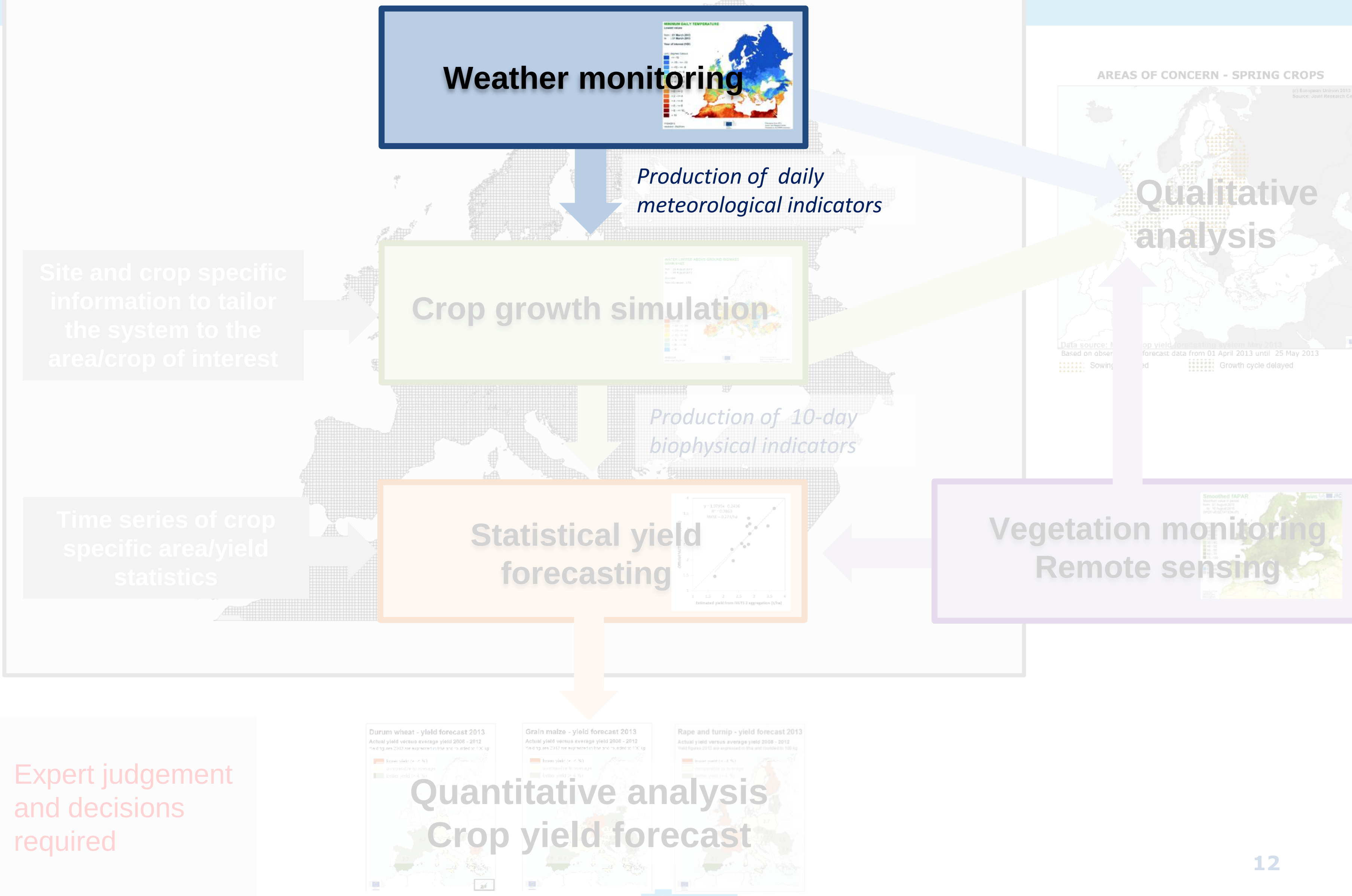
What?
Where?
How much?
Conditions?

Crop monitoring and yield forecasting

MCYFS - a model and data driven decision support system



System design



Meteorological DB

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Observed data

station interpolation
scaling forecast data
calculation of parameters

grid size 25 km * 25 km
quality checked

Near real time
Pan-European
Daily, 10- daily,
monthly,
seasonal,
long term average
METEO DB

Gridded data
Aggregated data

Temperature
Rainfall
Radiation
Vapour pressure
Windspeed
Evaporation
Evapotranspiration
Climatic water balance
Snow depth

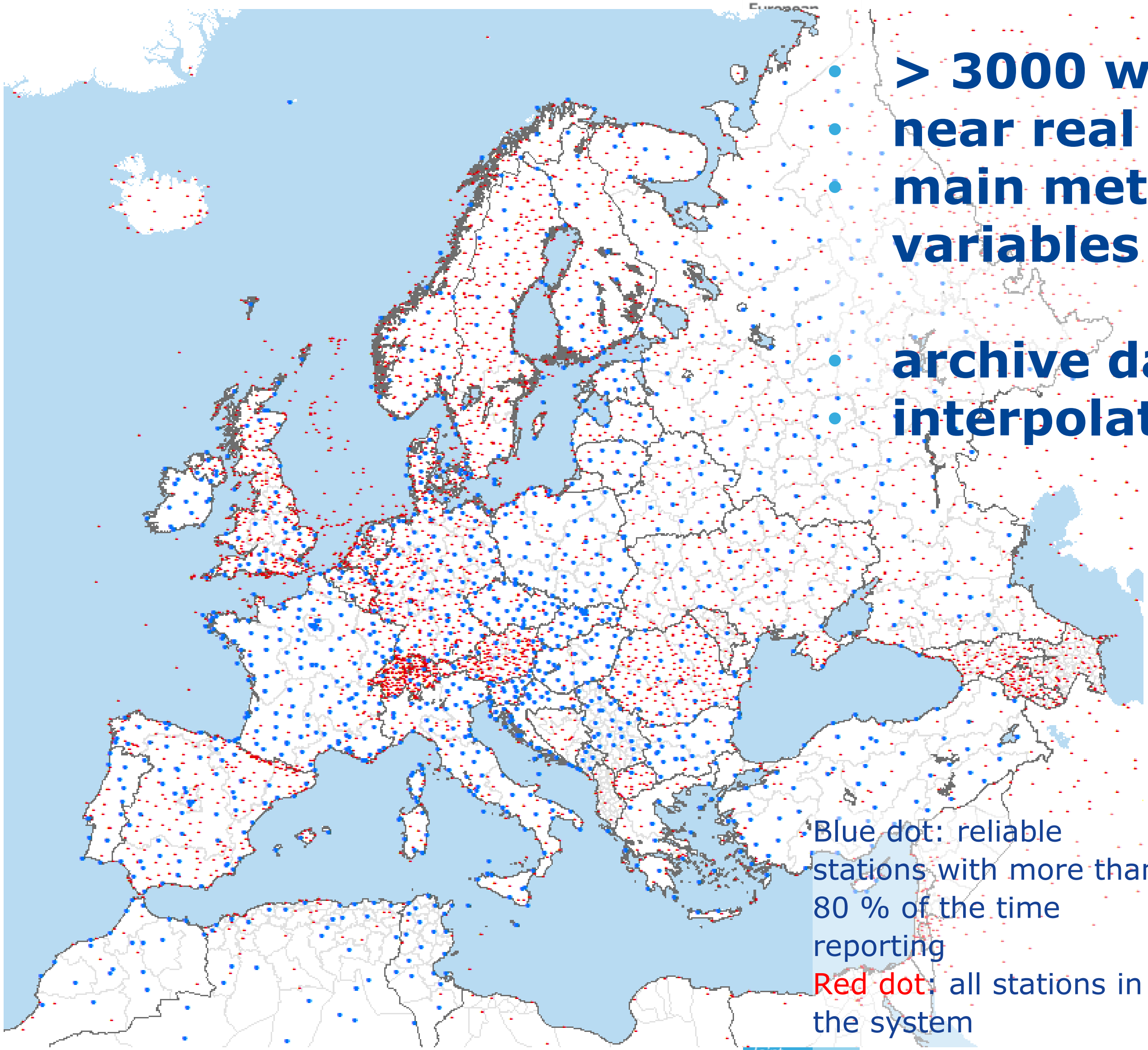
Weather forecast data
(ECMWF short to long range, seasonal)

Agro-meteorological analysis
Crop growth models

Active station net

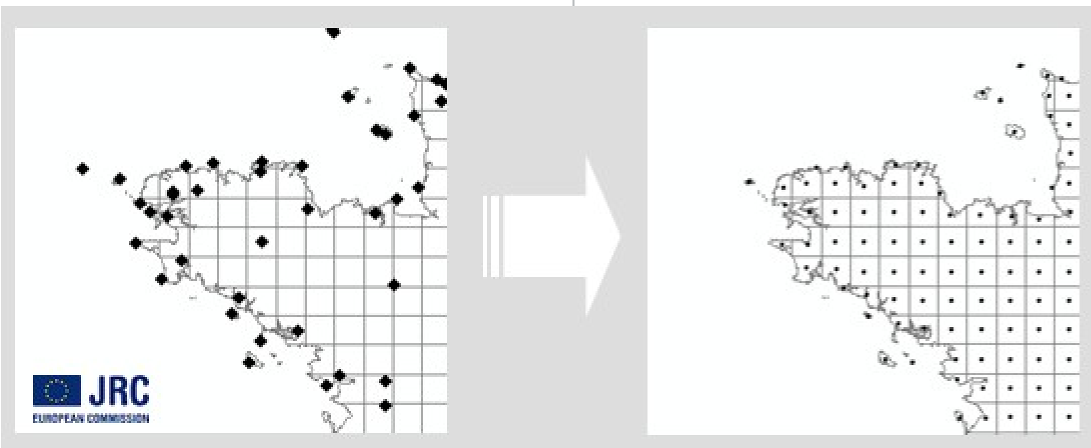
- > 3000 weather stations
- near real time
- main meteorological variables

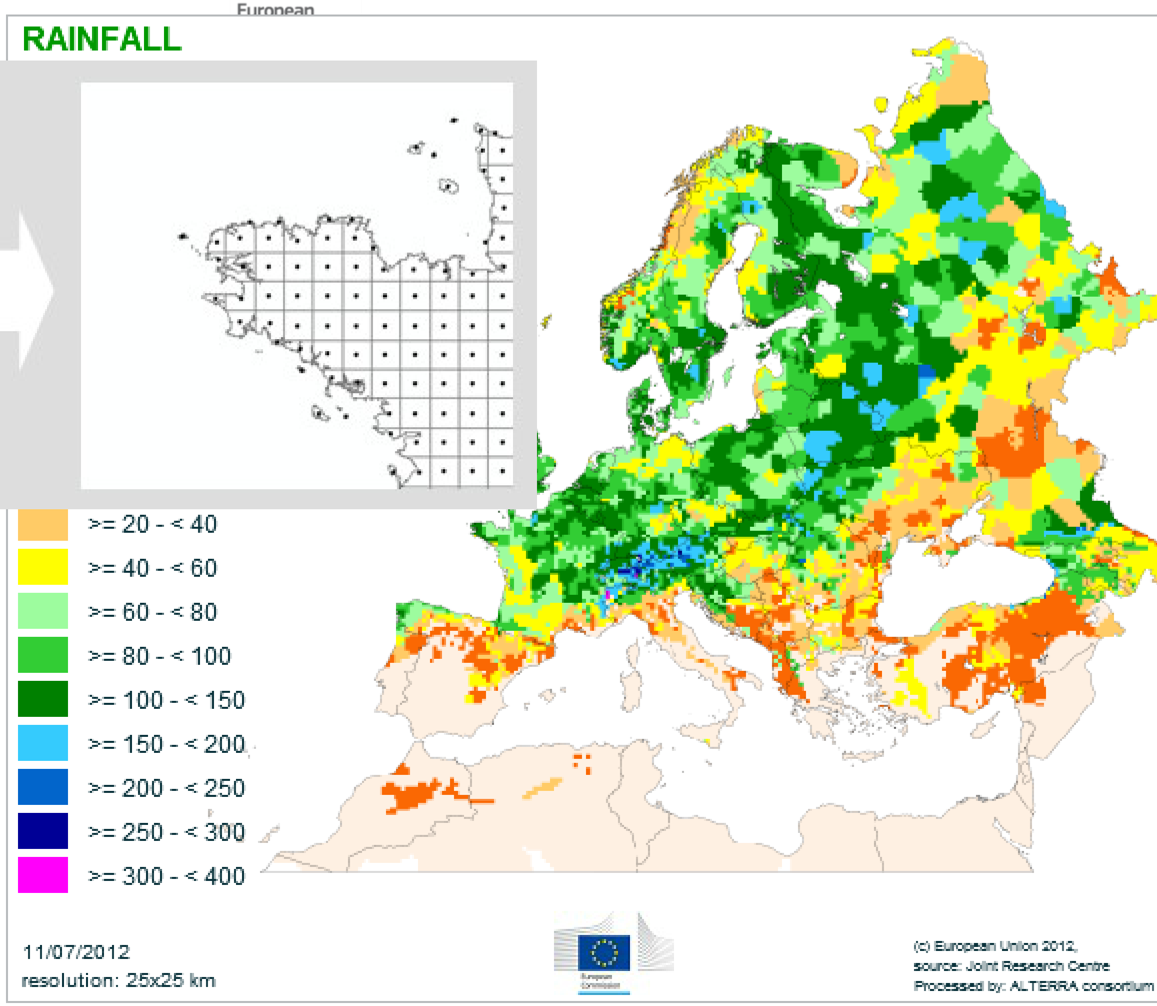
- archive data since 1933,
- interpolated since 1975



Blue dot: reliable stations with more than 80 % of the time reporting
Red dot: all stations in the system

Interpolation

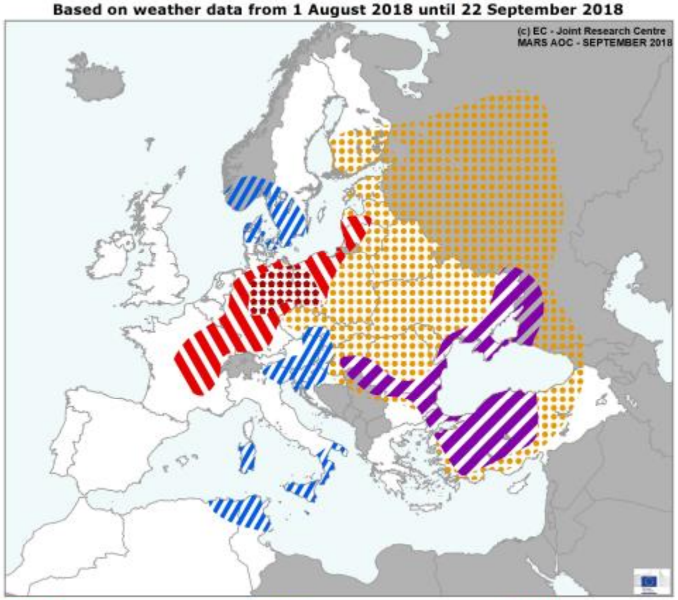




Meteorological analysis

AREAS OF CONCERN - EXTREME WEATHER EVENTS

Based on weather data from 1 August 2018 until 22 September 2018



Rain deficit

Rain surplus

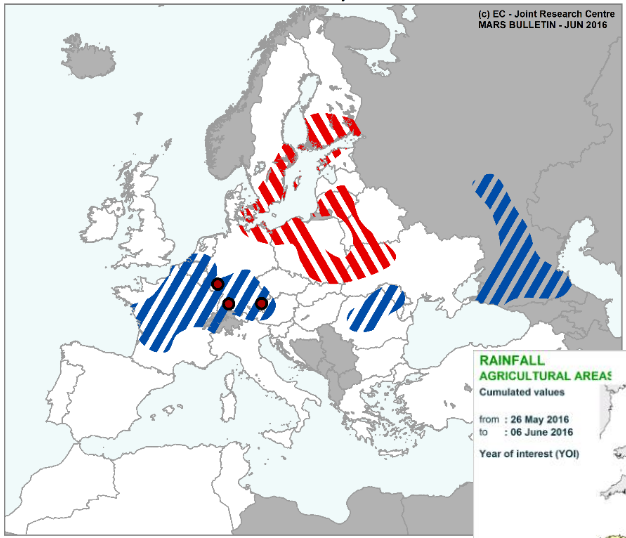
Drought

Temperature accumulation surplus

Heat wave

AREAS OF CONCERN - EXTREME WEATHER EVENTS

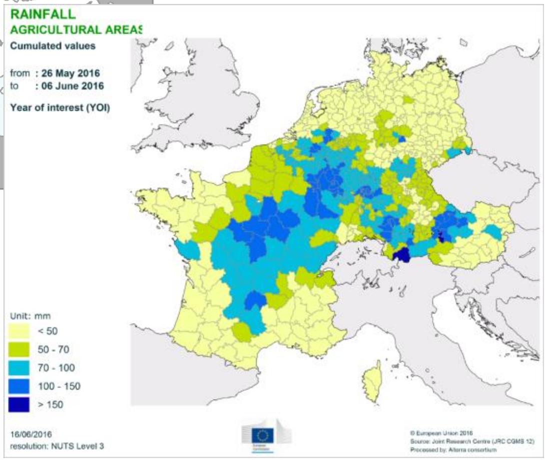
Based on weather data from 21 May 2016 until 17 June 2016



Rain surplus

Rain deficit

Hailstorms and heavy rains



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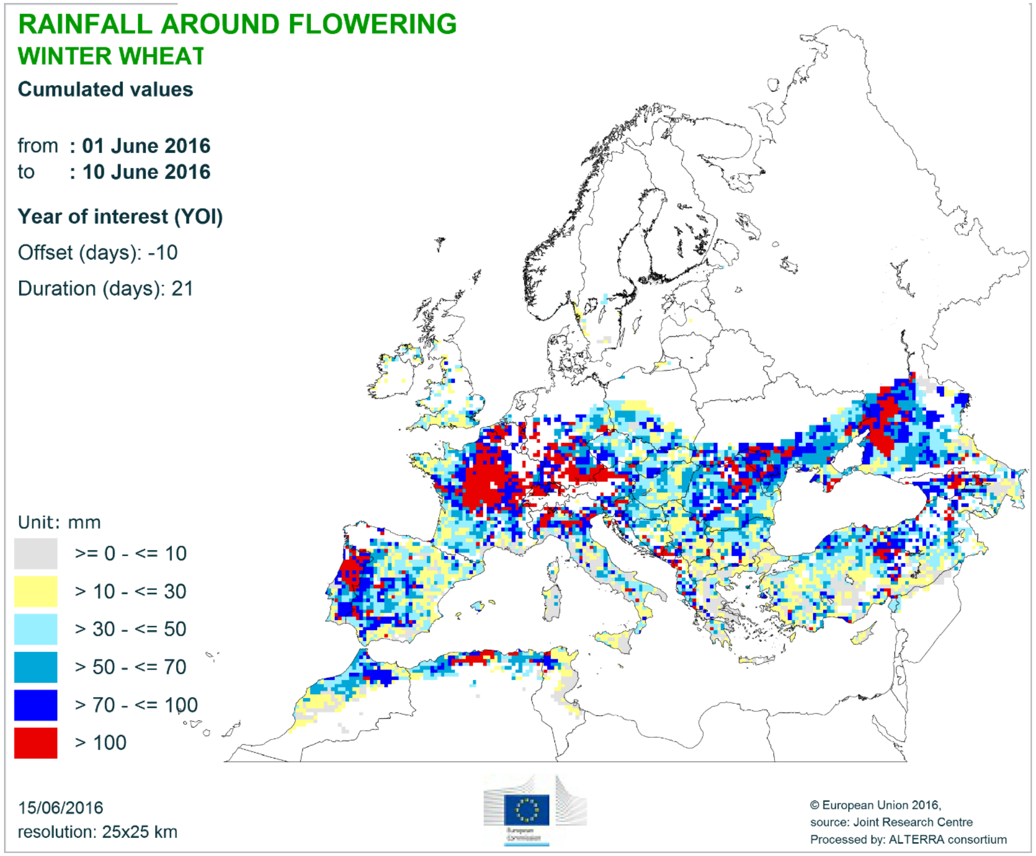
Agro-meteorological analysis

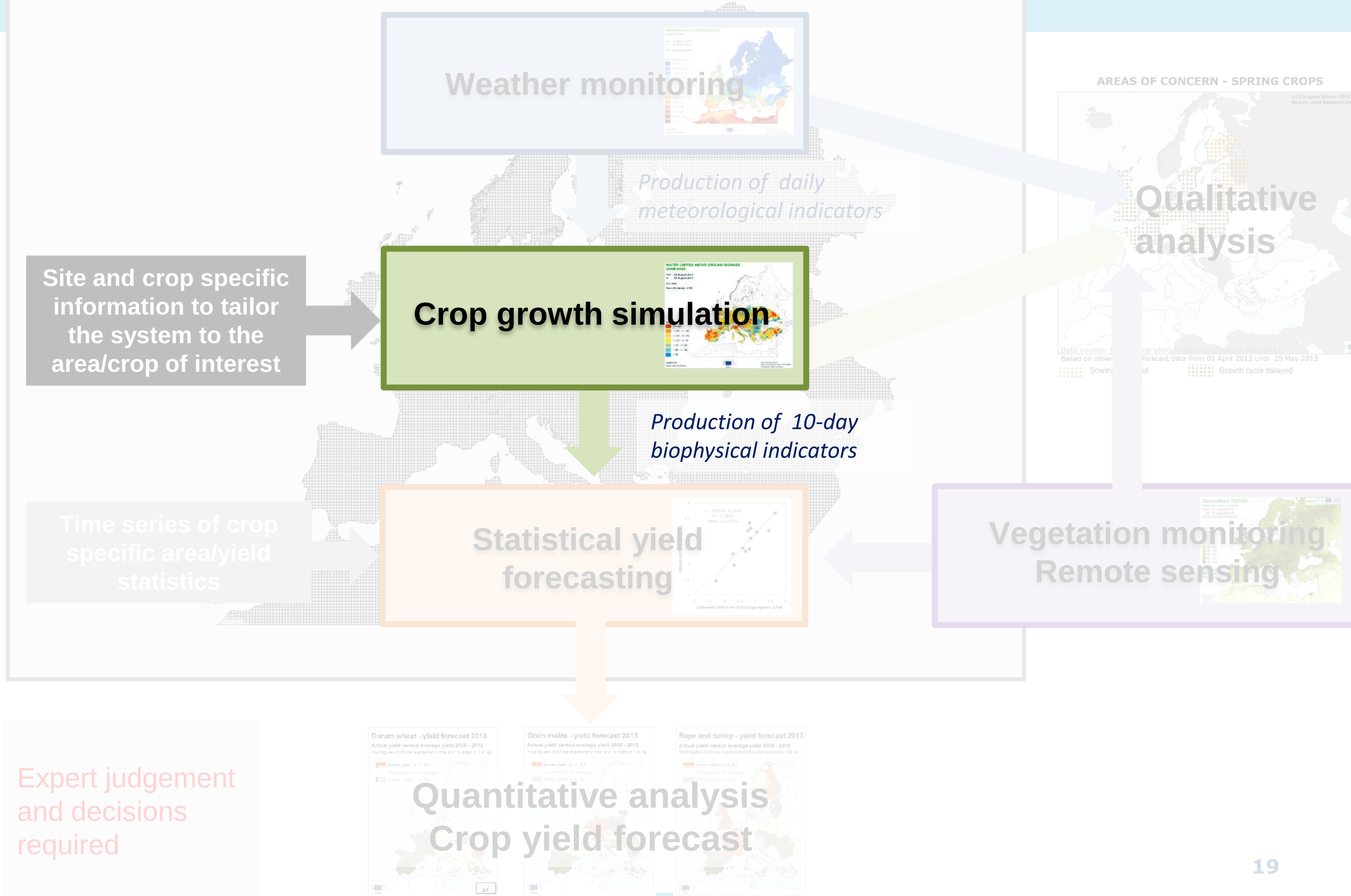
Typical events considered:

- excess of rain at sowing
- frosts at emergence
- droughts during vegetative growth
- rain at flowering
- dry spells at grain filling
- heat stress before maturity
- rain at harvest

Rainfall around flowering for winter wheat



System design



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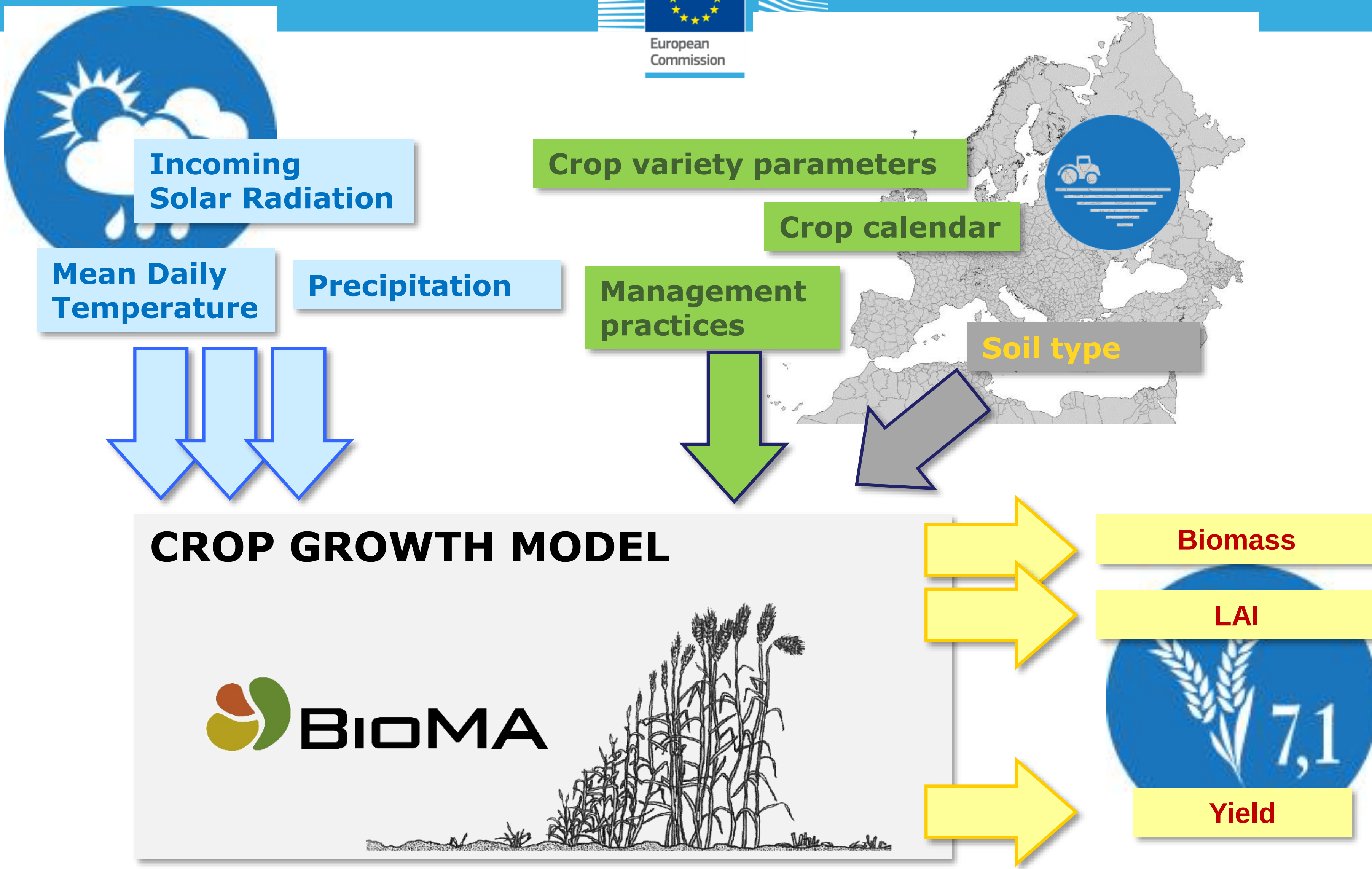
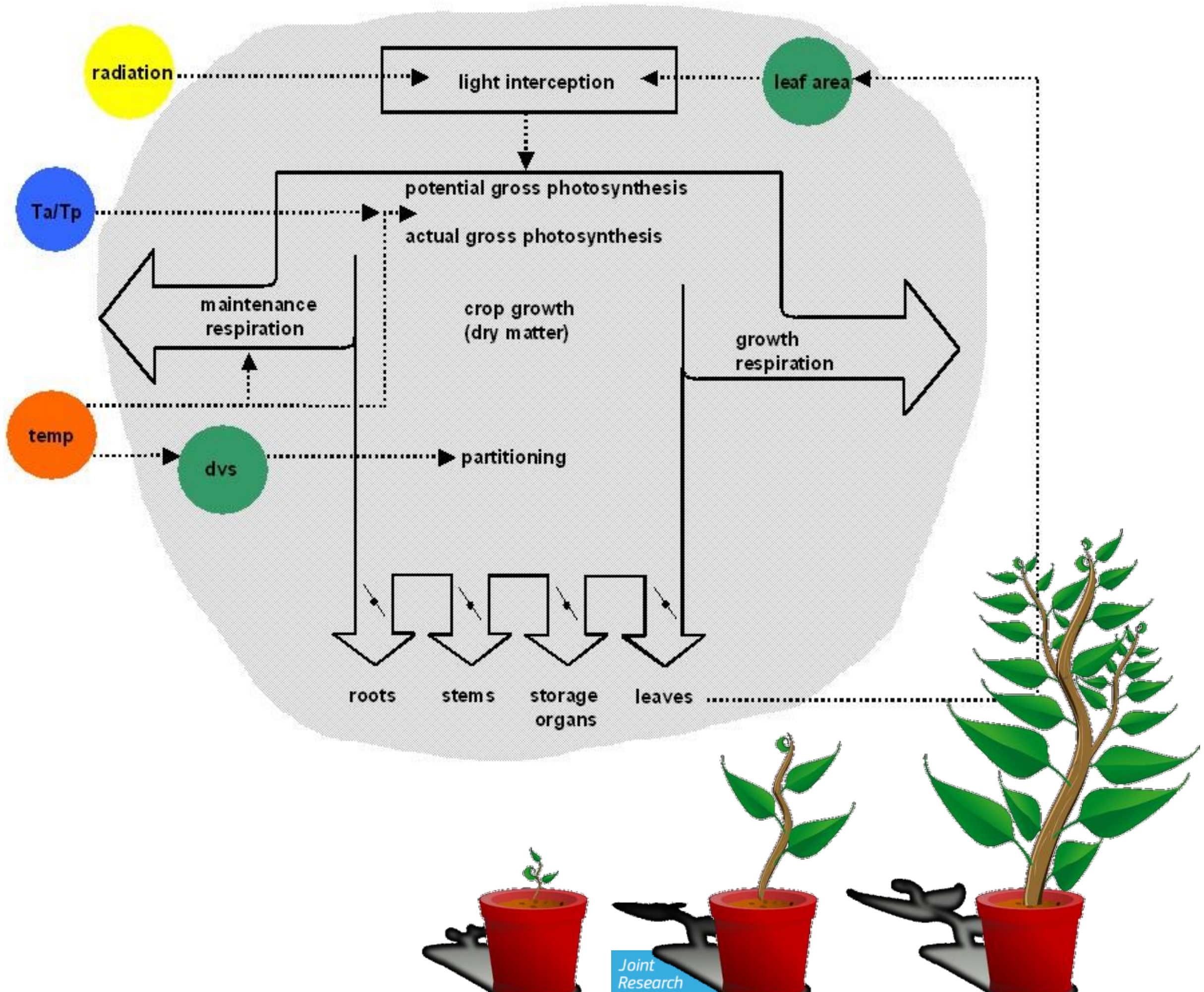
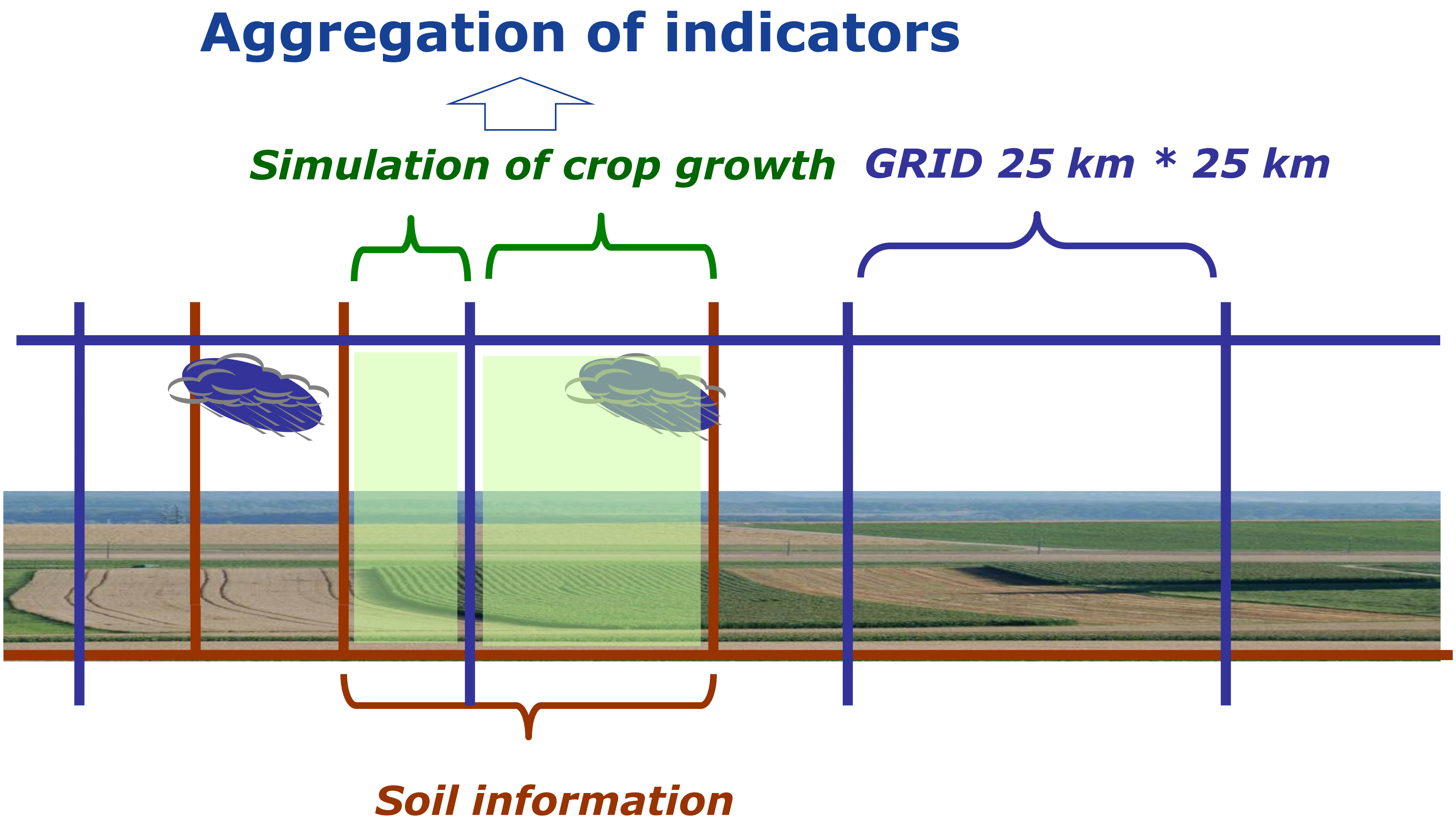


Crop growth simulation



Spatialized crop model



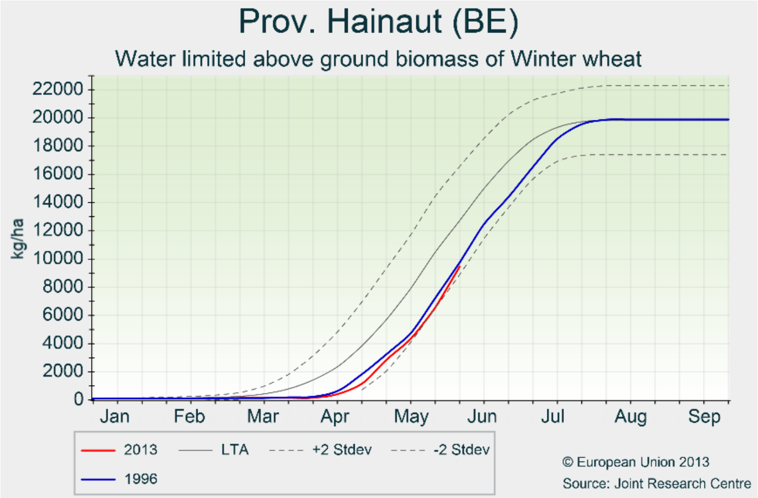
Indicators

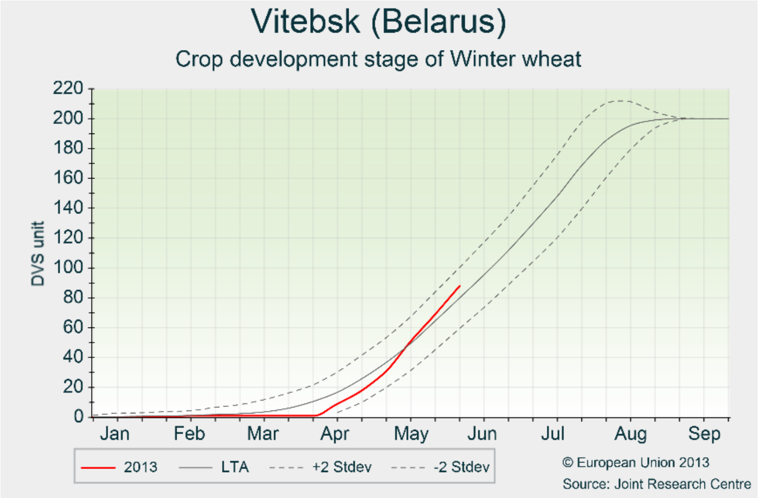
Water limited conditions and potential conditions per crop:

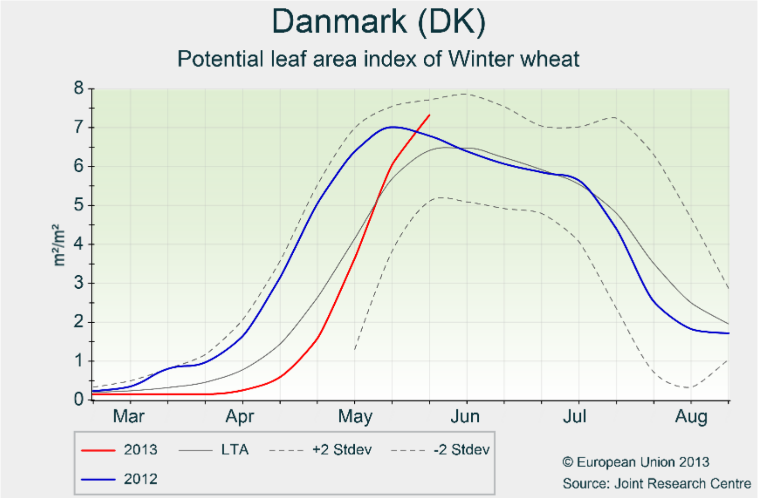
Above ground biomass
Storage organs
Leaf area index
Development stage
Relative soil moisture
Crop water requirements
Crop water consumption

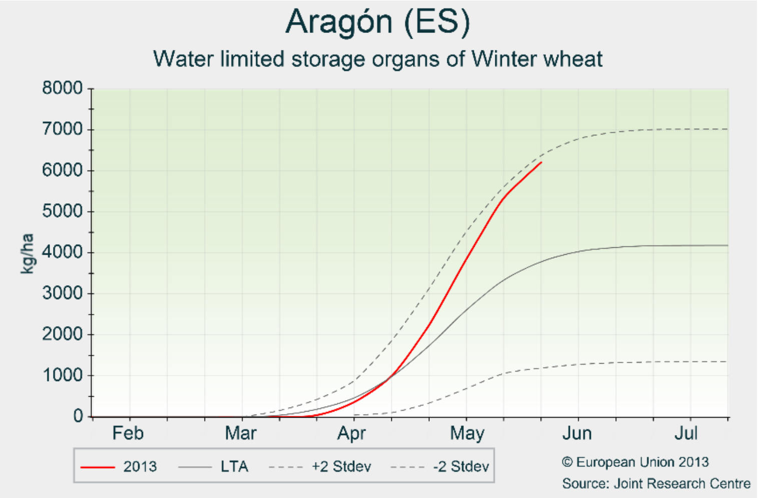
Winter wheat, spring barley, grain maize, rice, rye, sunflower rapeseed, sugar beet and potato

Outputs from the crop model

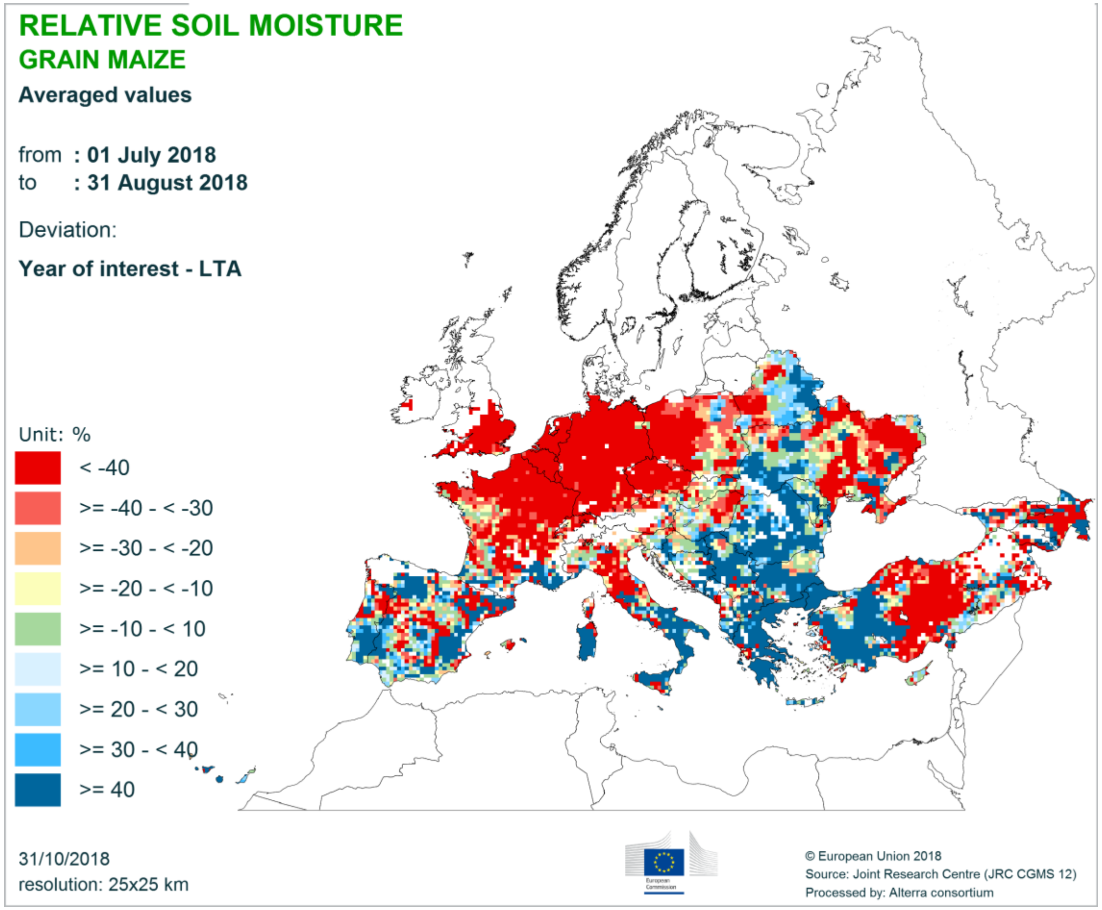




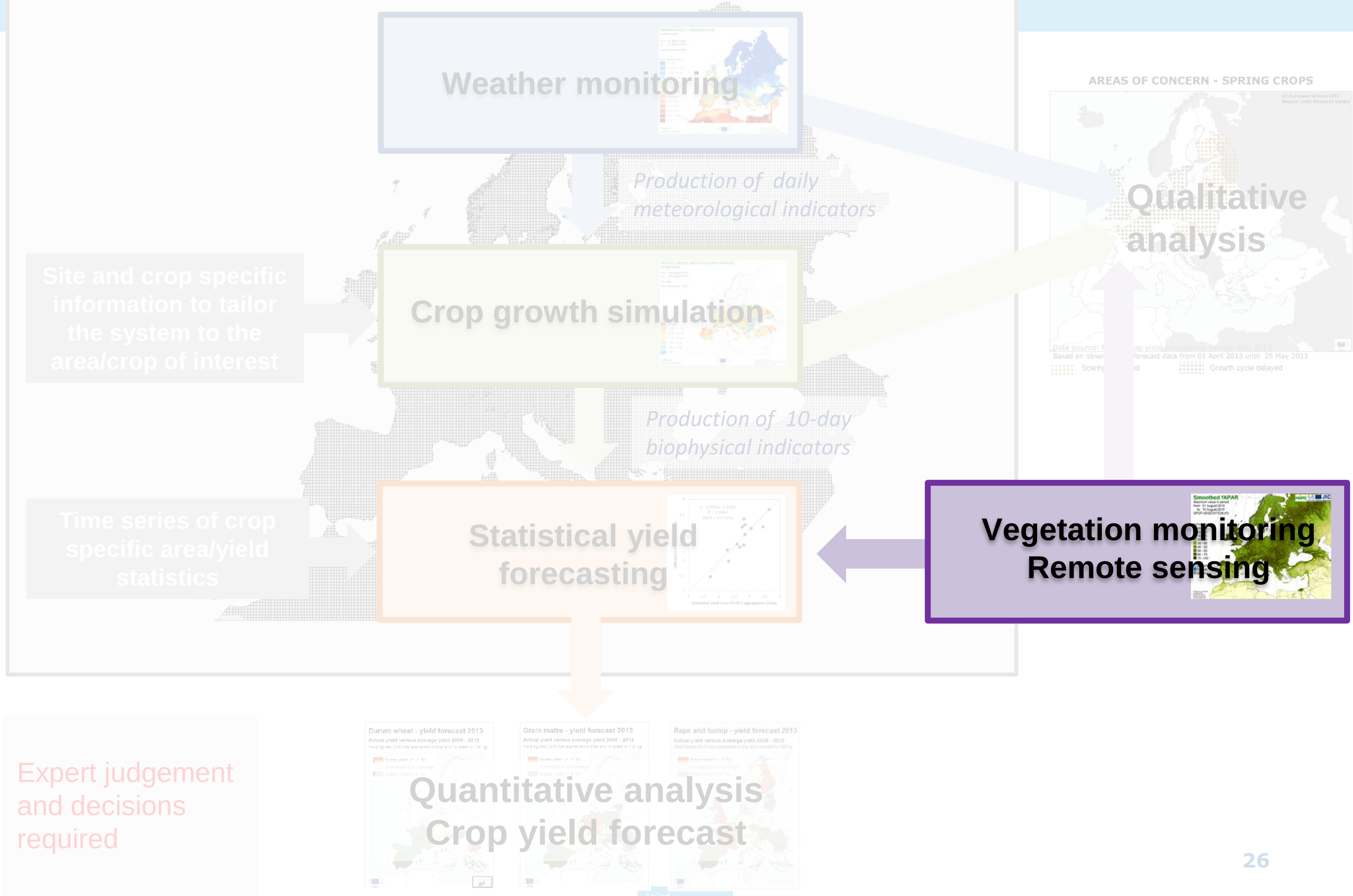




Outputs from the crop model



System design

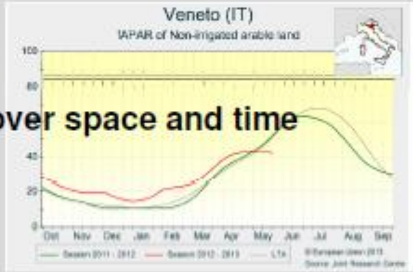


Remote Sensing data

Sensor	Processing	Indicators	Info extraction over space and time
MSG since 2005	Pan-European Daily, 10- daily, monthly, long term average	Land surface temp. Radiation (DSSF) Sunshine duration Snow cover	Difference analysis Time profile analysis Cluster analysis Similarity analysis Rank analysis Probability analysis Scenario analysis
NOAA AVHRR since 1981 METOP AVHRR from 2008 SPOT VGT since 1998	MARS RS DB image repository - original bands - atmospheric correction - geometric correction - quality flag	NDVI fAPAR	Qualitative / quantitative analysis
MODIS TERRA since 2000	- compositing - interpolation - smoothing - indicator computation - Information products	NDVI fAPAR	

Aggregation over space and time

Administrative unit
Agri-ecological zonation
Grid (25 km * 25 km)



Remote Sensing contribution

- Non crop specific analysis
  - Arable land monitoring
  - Pasture / grassland monitoring

Independent analysis for crops and pastures – **qualitative**

-Independent source of measured biomass activity

-Convergence of results

Independent analysis for crops – **quantitative**

-Crop yield forecasts (regional) based on RS derived vegetation state parameters only

Improvements meteorological infrastructure – **quantitative**

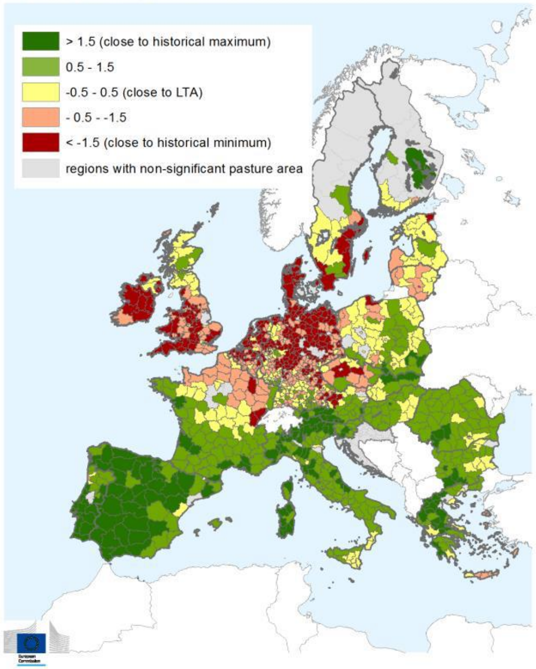
-Snow cover

-Radiation / MSG / station coefficients

Anomaly detection along the season

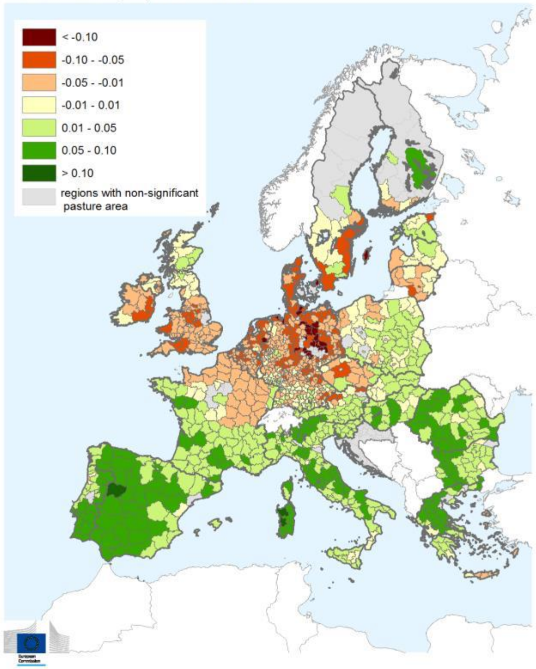
Relative index of pasture productivity

Period of analysis: 1 May - 31 July 2018
Index based on Copernicus GEOV2 fAPAR 10-day product.
Historical archive (LTA) from 1999 to 2017



fAPAR of Pastures
Absolute differences against LTA

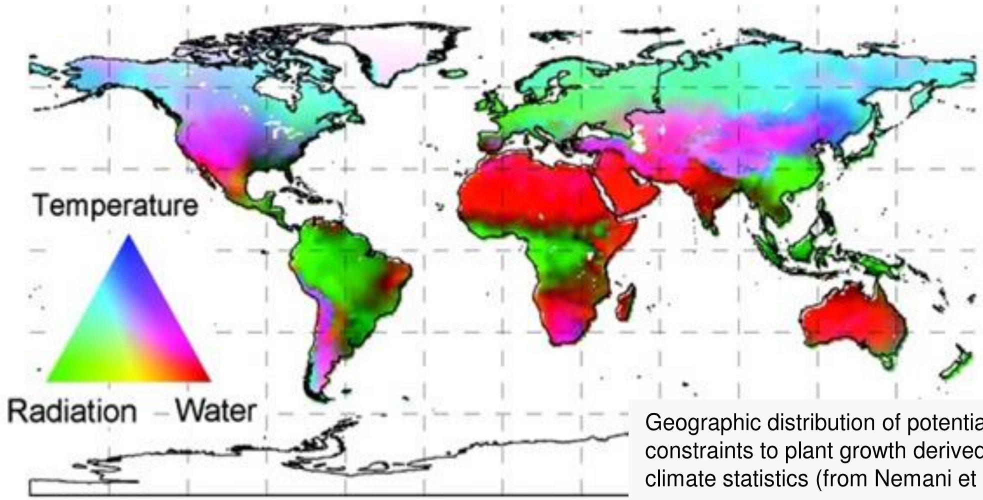
Period of analysis: 1 May - 31 July 2018
Index based on Copernicus GEOV2 fAPAR 10-day product.
Historical archive (LTA) from 1999 to 2017



Relative index is a z-score of the cumulated fNDVI (or fAPAR) during the growing season over pasture areas (CAPRI mask)

The way forward towards more quantitative, model-based approach requires systematic yield observations (statistics)

Global radiation



Geographic distribution of potential climatic constraints to plant growth derived from long-term climate statistics (from Nemani et al., 2003).

Calibration of solar radiation models for Europe using Meteosat Second Generation and weather station data

- Solar radiation is the most difficult parameter to obtain / few measuring stations
- Empirical solar radiation models / station coefficients
- MSG provides continuous source used to calibrate the empirical models at station level

System design

Weather monitoring

Production of daily meteorological indicators

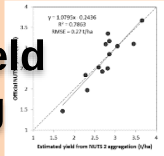
Site and crop specific information to tailor the system to the area/crop of interest

Crop growth simulation

Production of 10-day biophysical indicators

Time series of crop specific area/yield statistics

Statistical yield forecasting



Vegetation monitoring
Remote sensing

Qualitative analysis

AREAS OF CONCERN - SPRING CROPS

Quantitative analysis
Crop yield forecast

Expert judgement and decisions required

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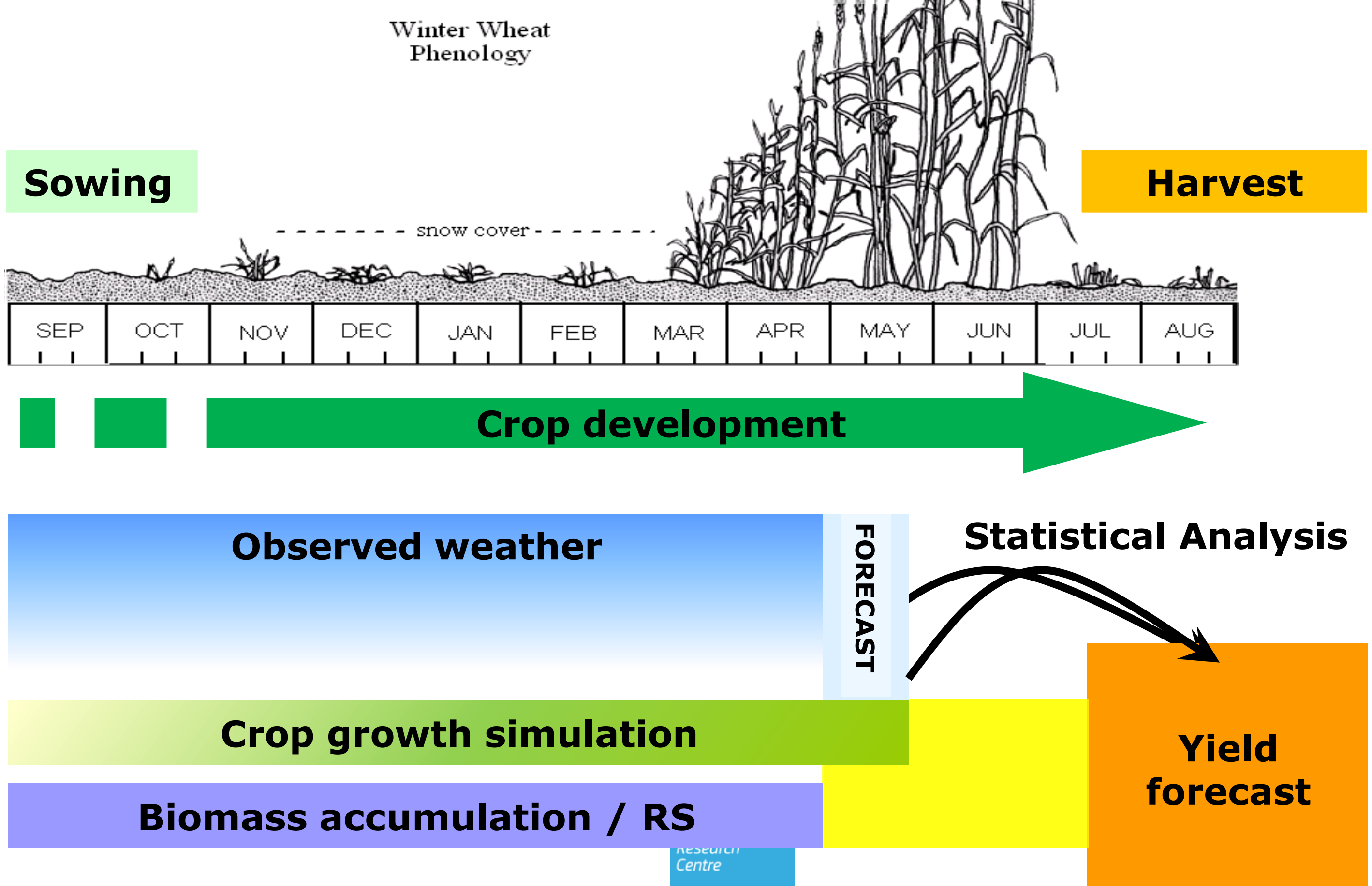
Forecasting approach

Weather has a significant effect on the crop yield, accounting for most of the inter-annual variability



Data requirements

Time series:
Crop growth indicators
Weather indicators
Remote sensing indicators
…

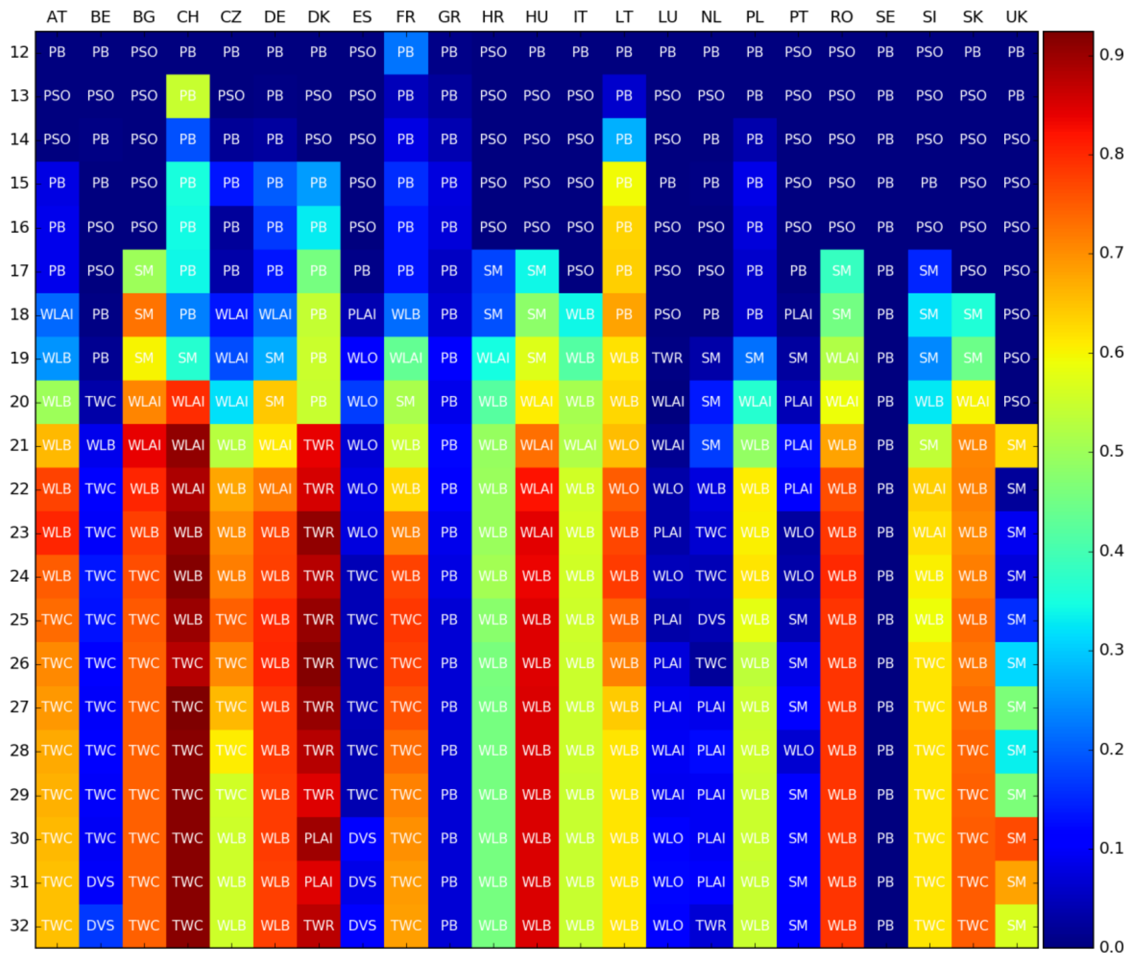
Time series:
Crop specific yield statistics
Crop specific area statistics

Build statistical relationship to forecast yields

Trend
Regression
Scenario

Regional statistical level determines aggregation of the indicators and level of yield forecasts – from regional to national

Regression coefficients along the season EU-28 for grain maize



Yield forecasts for major crops in Europe

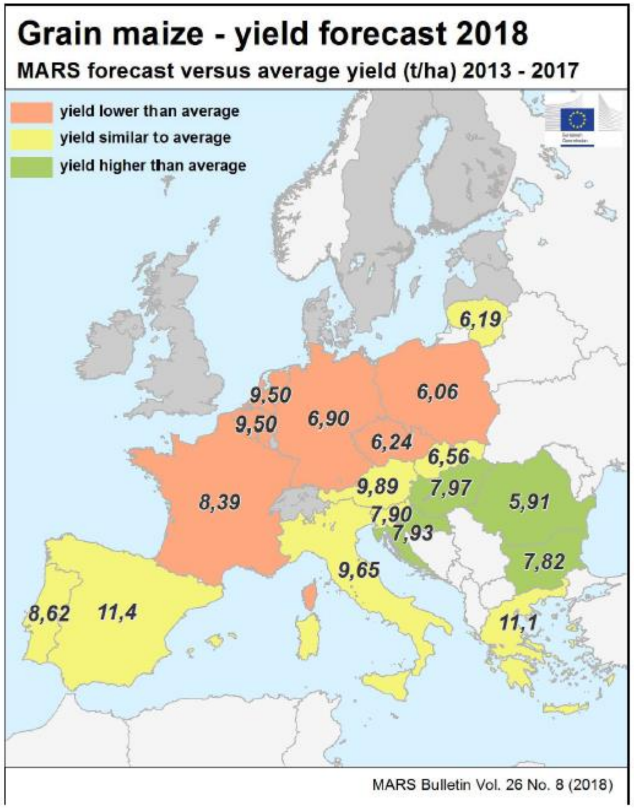
EU-28 level and crop groups

National level, single crops

From April to October each year

Crop	Yield (t/ha)				
	Avg 5yrs	July Bulletin	MARS 2018 forecasts	% Diff 18/5yrs	% Diff July
TOTAL CEREALS	5.56	5.38	**5.29**	-4.8	-1.7
Total Wheat	5.73	5.59	**5.49**	-4.2	-1.8
soft wheat	5.97	5.82	**5.70**	-4.5	-2.1
durum wheat	3.39	3.48	**3.47**	+2.3	-0.3
Total Barley	4.91	4.74	**4.71**	-4.0	-0.6
spring barley	4.25	4.13	**4.07**	-4.3	-1.5
winter barley	5.79	5.60	**5.61**	-3.1	+0.2
Grain maize	7.30	7.64	**7.57**	+3.6	-0.9

Country	GRAIN MAIZE (t/ha)				
	Avg 5yrs	2017	MARS 2018 forecasts	%18/5yrs	%18/17
EU	7.30	7.87	**7.57**	+3.6	-3.9
AT	9.76	10.0	**9.89**	+1.3	-0.6
BE	11.0	12.3	**9.50**	-14	-22
BG	6.24	6.44	**7.82**	+25	+22
CY	-	-	-	-	-
CZ	7.56	6.84	**6.24**	-17	-8.8
DE	9.74	10.5	**6.90**	-29	-35
DK	-	-	-	-	-
EE	-	-	-	-	-
ES	11.2	11.2	**11.4**	+1.8	+1.8
FI	-	-	-	-	-
FR	9.02	10.3	**8.39**	-7.0	-18
GR	10.8	9.92	**11.1**	+2.6	+11
HR	7.16	6.33	**7.93**	+11	+25
HU	6.84	6.89	**7.97**	+17	+16
IE	-	-	-	-	-
IT	9.71	9.30	**9.65**	-0.6	+3.7
LT	6.29	5.74	**6.19**	-1.6	+7.9
LU	-	-	-	-	-
LV	-	-	-	-	-
MT	-	-	-	-	-
NL	10.5	13.4	**9.50**	-9.8	-29
PL	6.43	7.15	**6.06**	-5.7	-15
PT	8.45	9.24	**8.62**	+2.0	-6.7
RO	4.55	5.95	**5.91**	+30	-0.7
SE	-	-	-	-	-
SI	8.00	7.11	**7.90**	-1.2	+11
SK	6.36	5.68	**6.56**	+3	+16
UK	-	-	-	-	-



https://ec.europa.eu/jrc/en/mars/bulletins

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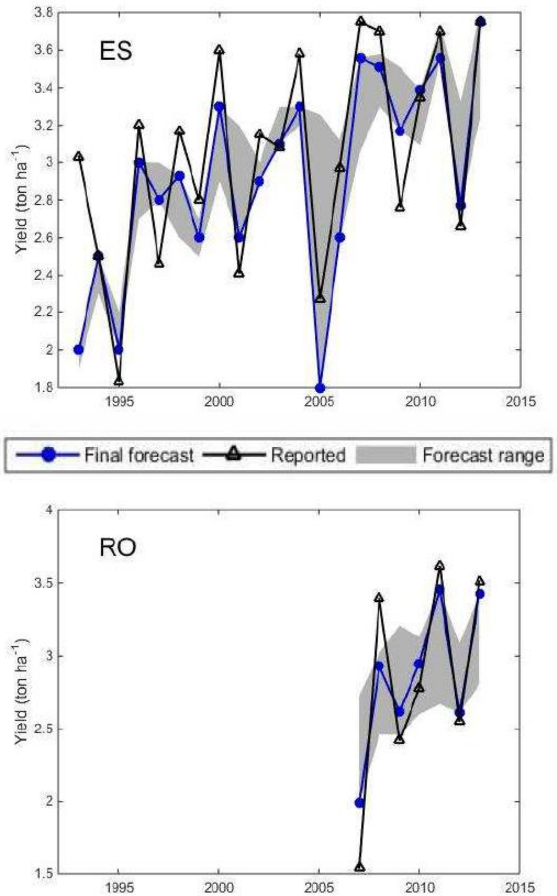
Crop monitoring and yield forecasting

- The primary user is the **Directorate General for Agriculture and Rural Development (DG-AGRI)** of the European Commission
  - quantify the production estimates for crop supply
  - identify regions with exceptional (mostly weather related) challenges that might require a policy response (impact future market supply and farmers' income)
  - Build supply and demand balance sheets (anticipate market developments in subsequent year)
  - Monitor crop conditions and forecasting in third countries (export-import)
  - Agro-meteorological analysis answers to Member States governments (i.e. concerning the impact of extreme events)

- **Eurostat, media, traders, academia, farmers, ...**

Crop monitoring and yield forecasting



- Intraseasonal assessment of wheat forecasts (2450 forecasts for 362 forecast years)
  - Medium yielding years are forecasted accurately in July
  - Low and high yielding years are over (10%) and underestimated (8 %)
  - Forecast accuracy of high yielding years improves during the season
  - Extreme events affecting yields late in the season remain difficult to forecast

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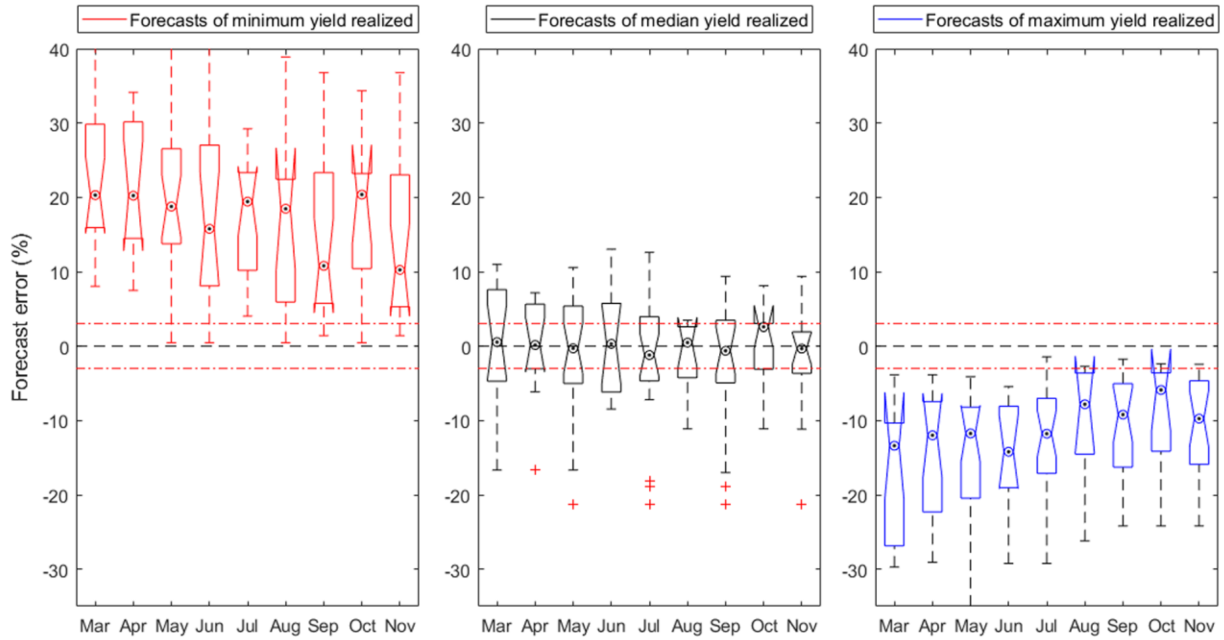
Crop monitoring and yield forecasting

- Challenge: forecasting of yields in years with extreme climatic events



In-season development of forecast error for EU in years that resulted in minimum, median and maximum yields (van der Velde et al., 2018)

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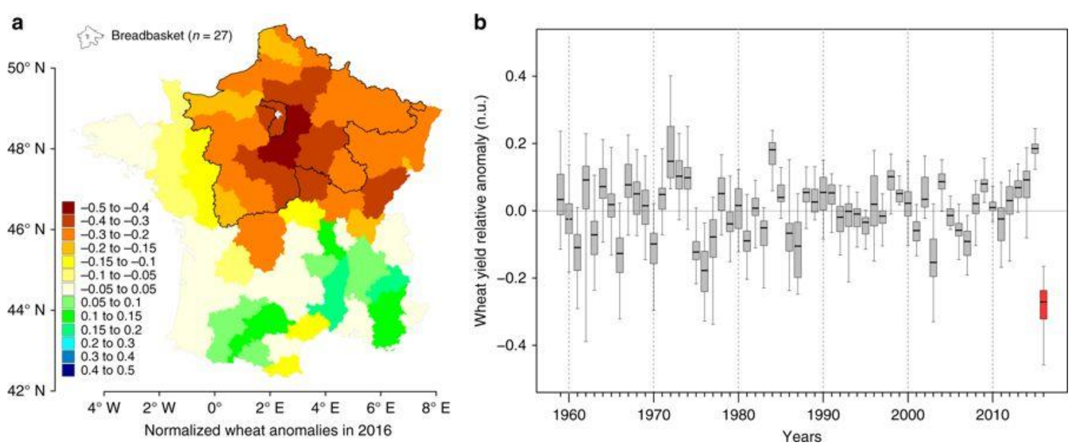
Crop model improvements

- Crop yield forecasting in extreme years
  - Extreme yield loss in the breadbasket of France in 2016
  - Crop yield forecasting system(s) failed to anticipate this event
    - New type of compound extreme with conjunction of abnormally warm temperatures in late autumn and abnormally wet conditions in the following spring (Ben-Ari et al., 2018)



Spatio-temporal pattern of 2016 extreme yield loss (Ben-Ari et al., 2018)

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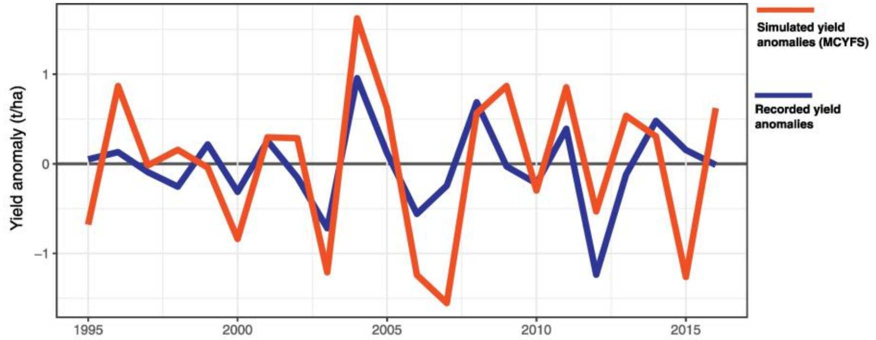
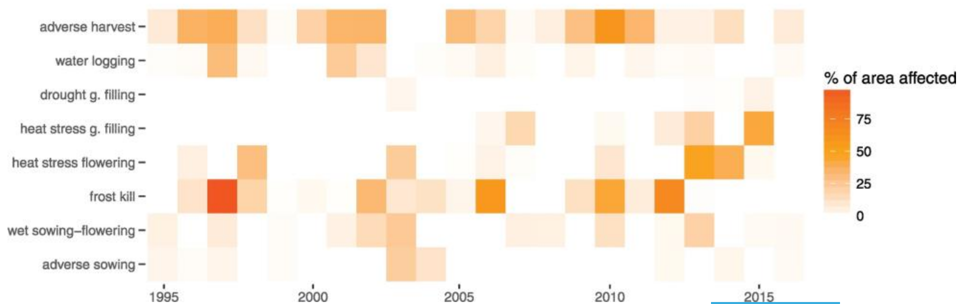
Crop model improvements

- Crop yield forecasting in extreme years
  - Crop model representation of relevant physiological processes and impact of climate extremes (heat stress, drought stress, water logging, pests and diseases, cold stress)
  - Agro-management (fertilization, field operations, cultivar selection, rotation patterns, ...)



Recorded and simulated winter wheat yield anomalies in the Czech Republic (Ceglar et al., 2018).



Percentage of winter wheat area affected by adverse weather events during different growth stages.

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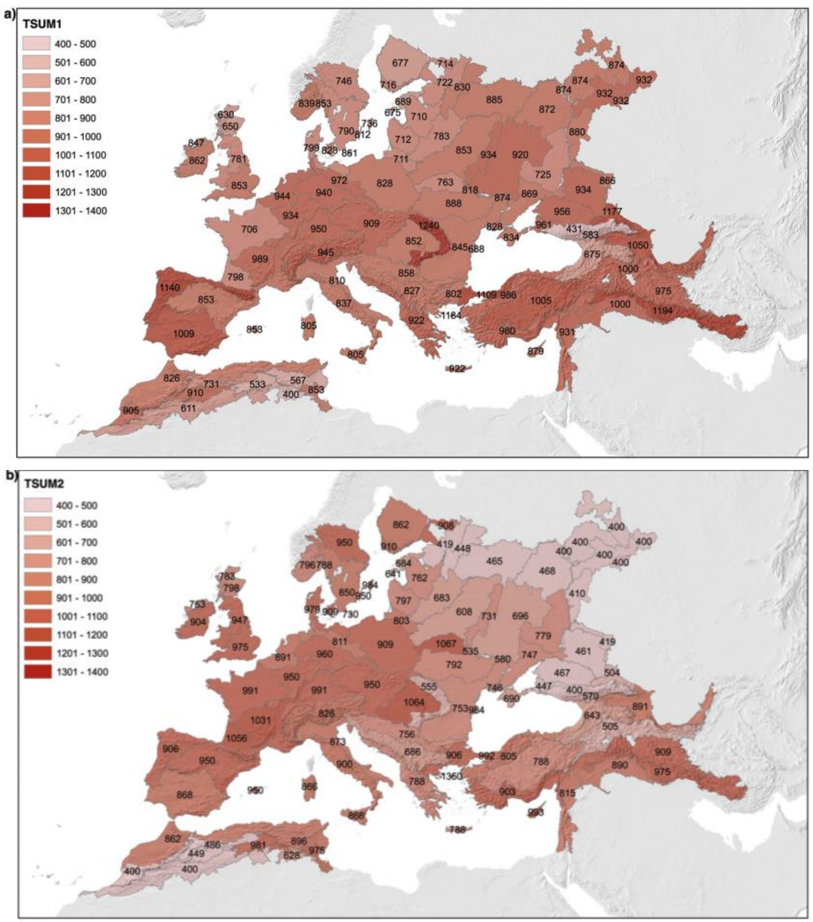
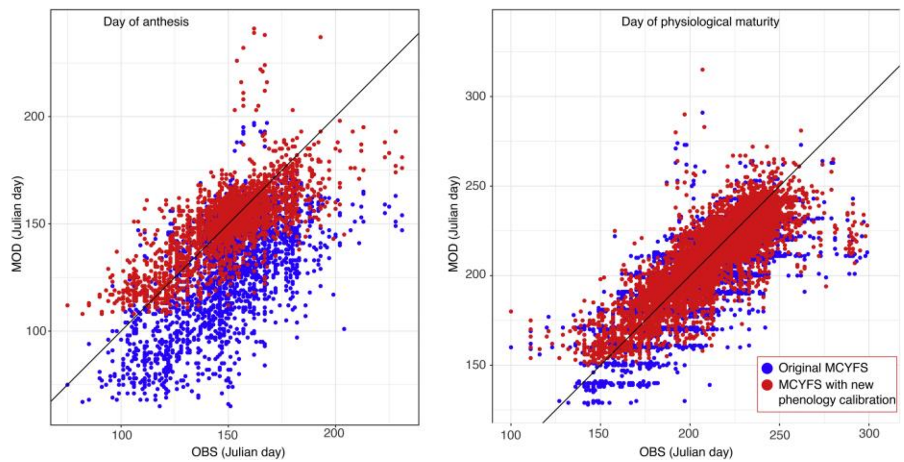
Crop model improvements

- Simulation of phenological development





Simulated vs observed anthesis and physiological maturity dates for winter wheat in Europe before (blue) and after (red) calibration (Ceglar et al., 2018)

Crop model improvements

- Crop yield forecasting in extreme years
  - Crop model improvements to account for processes relevant during extreme weather events
  - Better representation of spatial distribution and phenology (remote sensing)
    - Developments that foster open access to detailed geospatial reference datasets in combination with available high-resolution satellite images will enable a much better characterisation of impacts at field level.
  - Agricultural system modelling
    - More integration among disciplines and data are needed to advance agricultural models (biophysical and economic modellers, plant and animal breeders, pest and disease researchers)
    - Open, harmonized data (metadata, standards, protocols)
    - Modularity and interoperability

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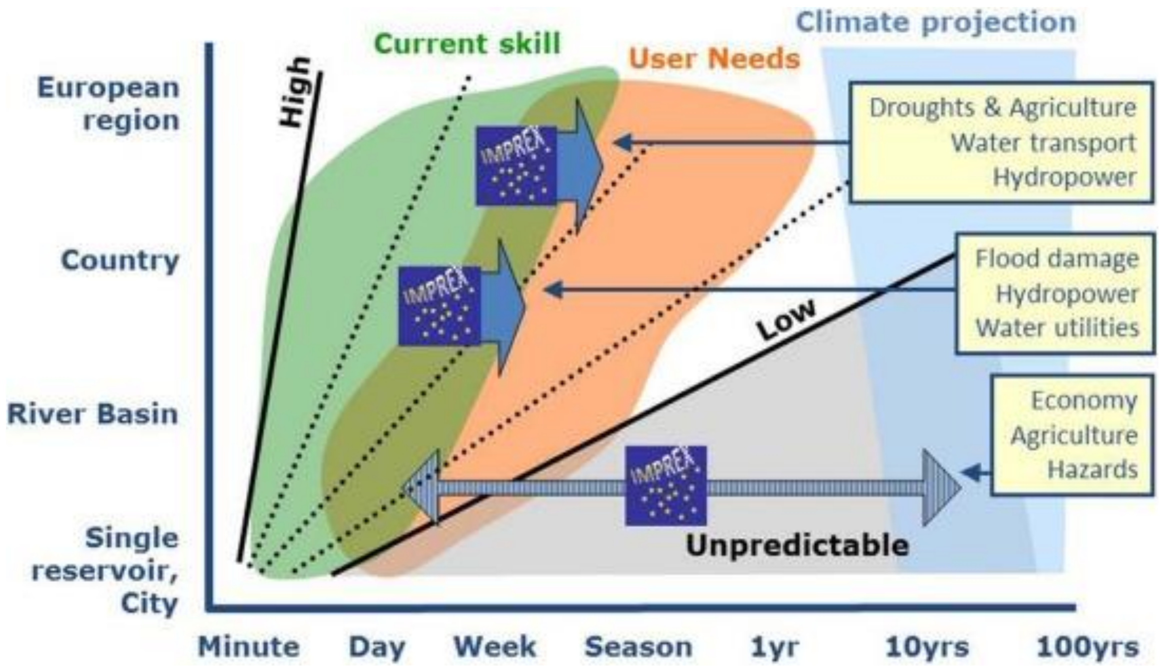
Seasonal climate forecasts in agriculture

- Predictability and forecast lead times are dependent on spatial scales, climate predictions beyond certain time scale are not feasible



Van den Hurk et al., 2016

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Seasonal climate forecasts in agriculture

- It has been shown that seasonal climate predictions represent a valuable source of information for the agricultural management process (Iizumi et al. 2018; Lalić et al., 2017; Challinor et al., 2005; Hansen, 2005)

- Understanding the relationship of climate variability and extremes with past crop production is of high relevance when assessing the resilience of agricultural production in future climate conditions
  - Short-term (week, month, season): farmer‘s decissions to apply short term-adaptation measures, such as: field preparation, selection of varieties, irrigation, protection against diseases, timing of harvest, ...

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Seasonal climate forecasts in agriculture

- Seasonal forecasting in Europe poses a great challenge due to the poor skill of local surface variables (especially precipitation)
  - Skill for local surface climate variables only for particular seasons and events (Frias et al., 2010; Shongwe et al., 2007)
- Prediction of extreme summers, such as the one in 2003 remains challenge

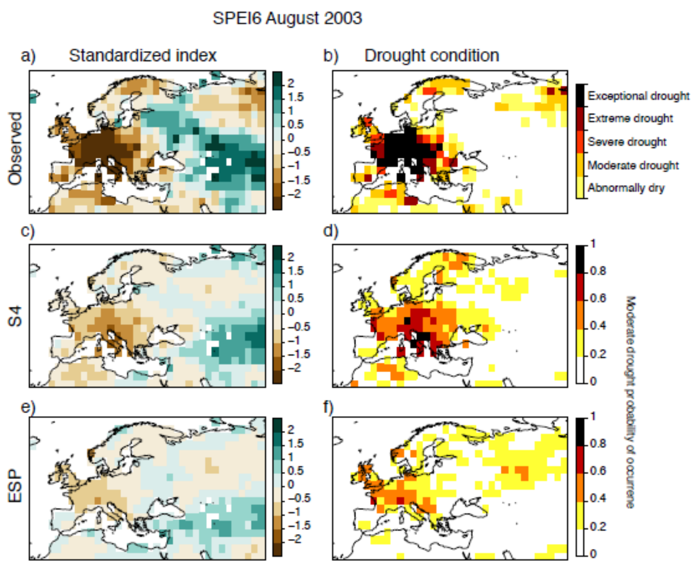

Figure 5. Observed 6-month SPEI for August 2003: a) SPEI6 values and b) observed drought conditions (based on Table 1). Predicted SPEI6 for August 2003 with the start date of May: c) S4 ensemble mean; d) S4 probability for moderate drought occurrence (SPEI<0.8); e) ESP ensemble mean and f) ESP probability for moderate drought occurrence.

(Turco et al., 2017)

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Seasonal climate forecasts in agriculture

- Seasonal forecasting of crop yield have been shown as valuable option for European agriculture (e.g. Cantelaube and Terres, 2005)

- Many efforts in recent years to improve the quality and usability of seasonal forecasts

- Although, limited skill of seasonal forecasts is observed over Euro-Meidterranean region
  - there are areas showing reasonably good performance (Doblas-Reyes et al., 2003)
  - key aspects of European and north-American winter climate and the surface NAO are highly predictable months ahead (Scaife et al., 2014)

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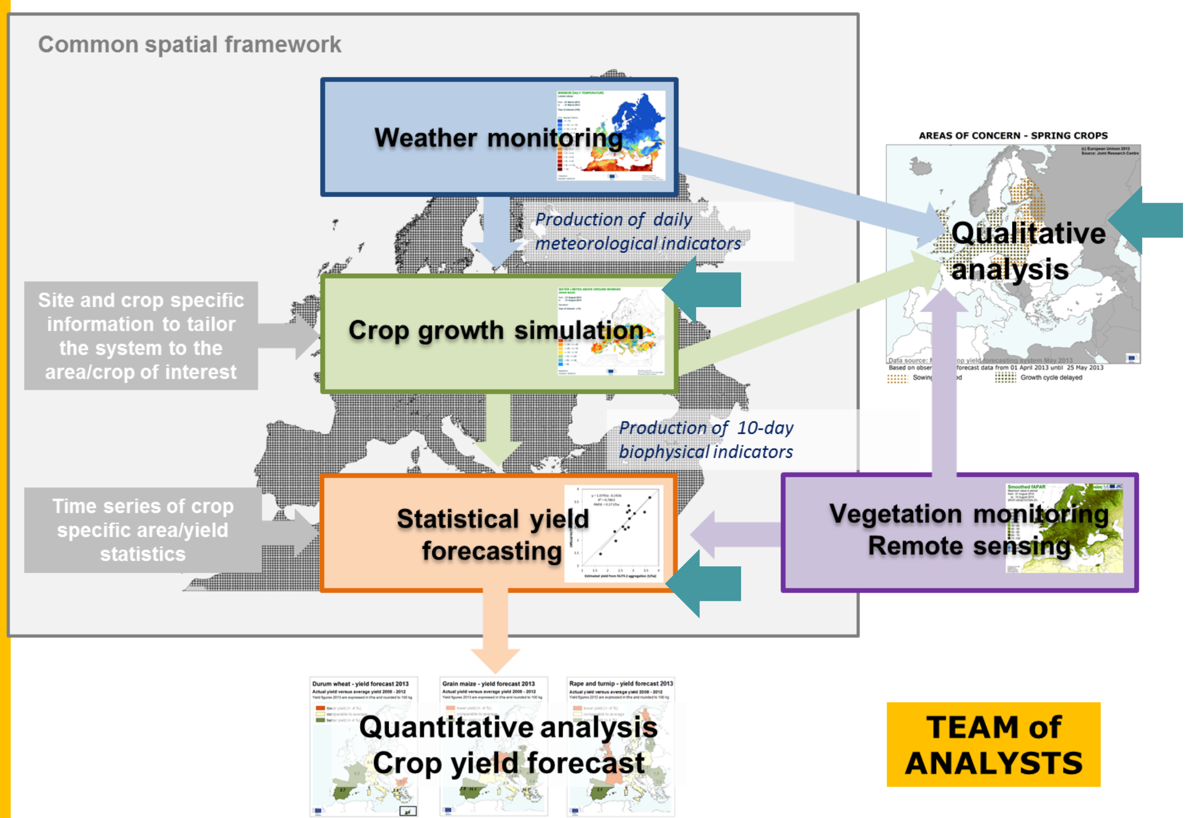
Seasonal climate forecasts in agriculture

Expert decisions along all steps of the process

MCYFS - a model and data driven decision support system



Monthly/seasonal forecast entering point

Important to consider:

- time in the season
- meteorological variable
- skill of forecast
- spatial scale

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Seasonal climate forecasts in agriculture

- Utilize components of climate seasonal forecasts, where noticeable skill is observed (e.g. large scale circulation patterns)

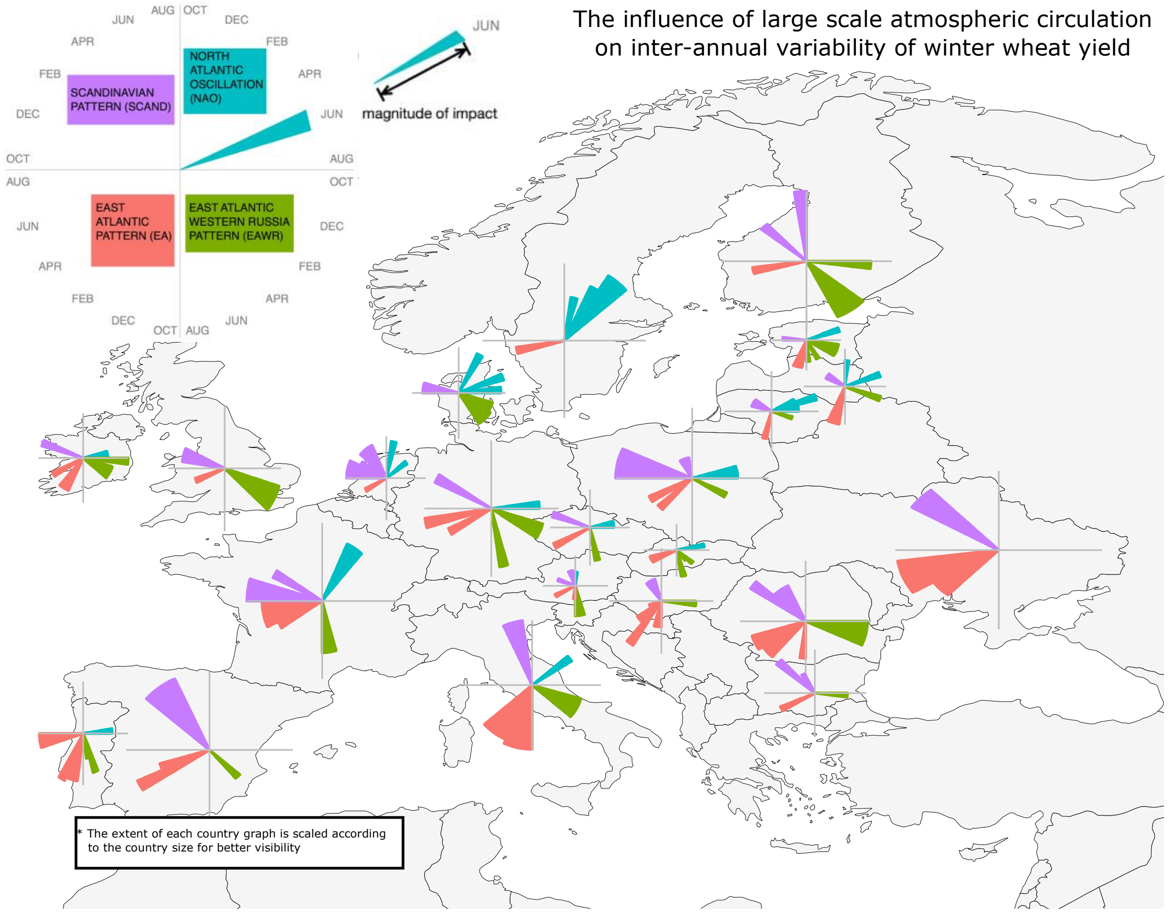
- Crop yield (especially when assessed on large scale) is dependent on slowly-varying components of climate system

- There is link between large-scale atmospheric mechanisms and extreme weather over Europe (e.g. Krichak et al., 2014; Toreti et al., 2010)

- If relationship exists between the large-scale atmospheric anomalies and climatic events during the crop growing season, seasonal forecast might help us to improve the quality of seasonal crop yield forecasting

- Explore dynamical sources of crop yield predictability, originating from large-scale atmospheric circulation

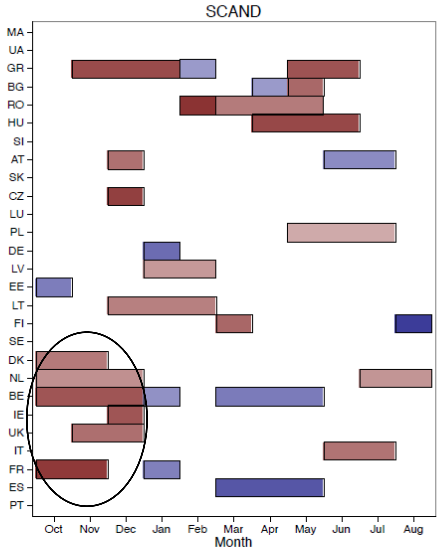
Seasonal climate forecasts in agriculture

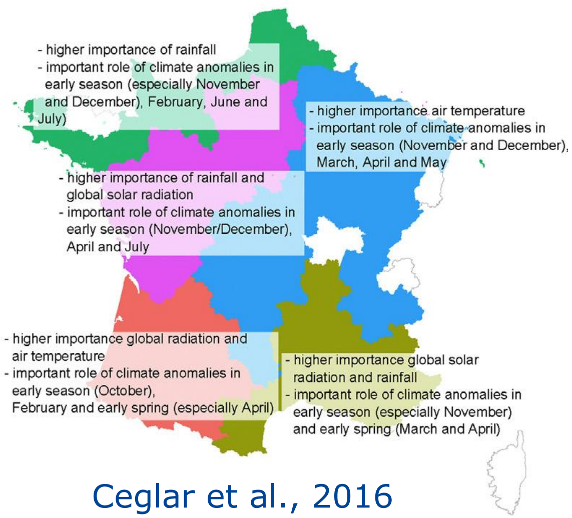


Large-scale atmospheric circulation impact on winter wheat yields (Ceglar et al., 2017)

Seasonal climate forecasts in agriculture

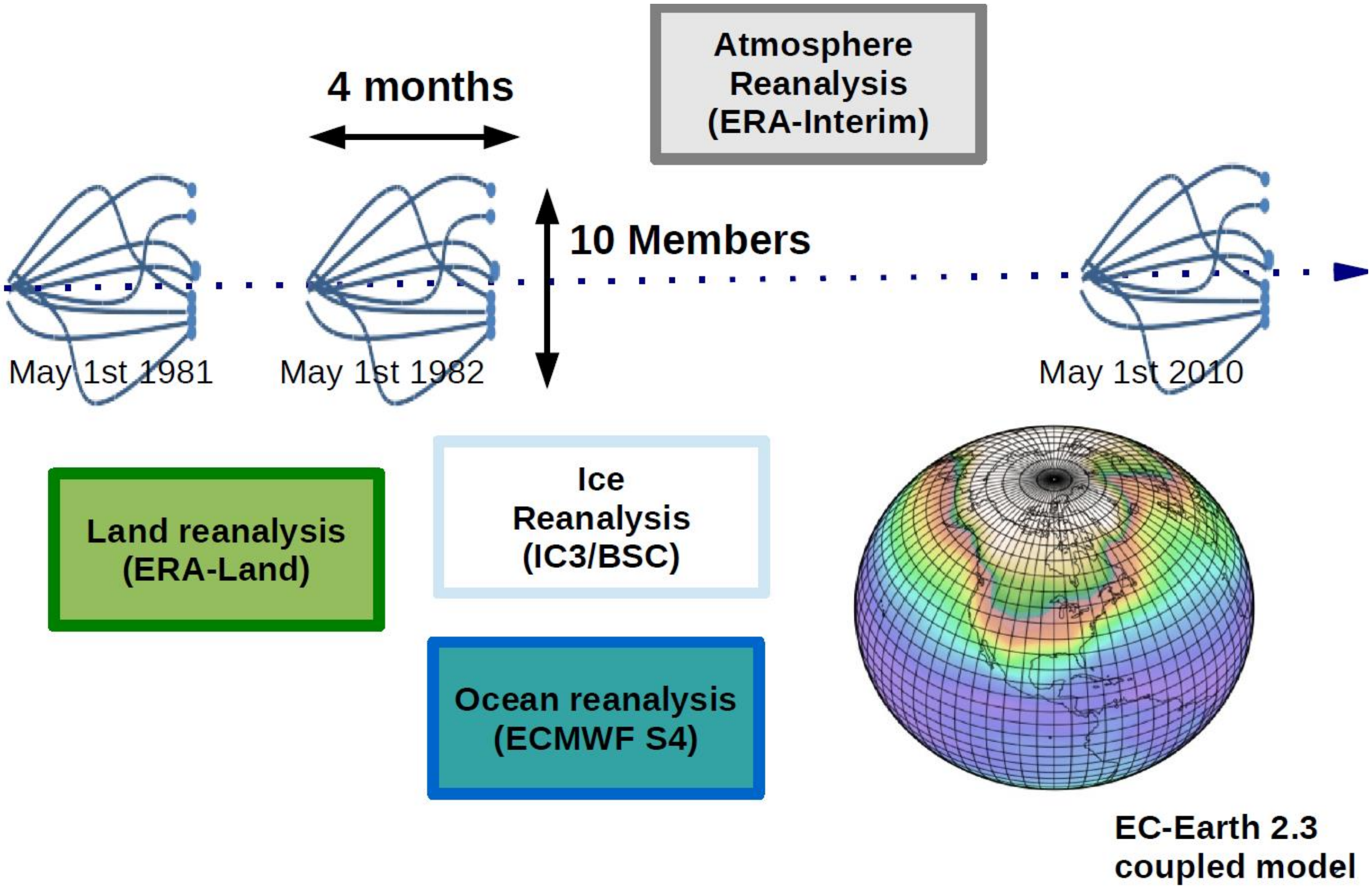
- Do these results have „bio-physical" meaning?
  - Assessment of correlations between large-scale atmospheric indicators and regional anomalies of precipitation and temperature





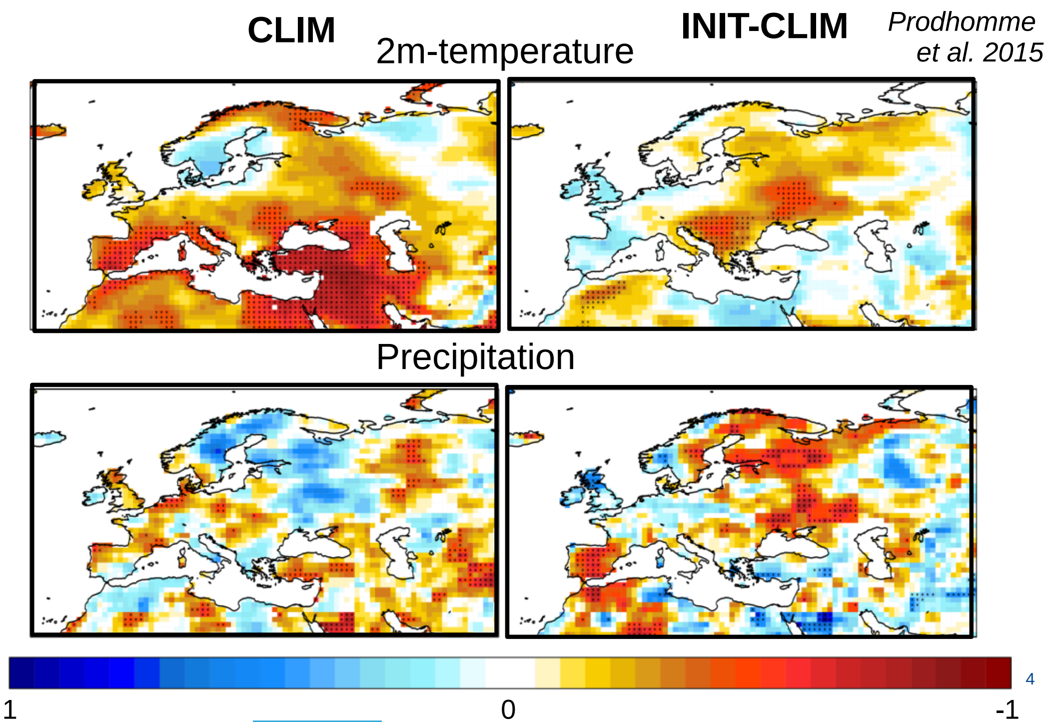
Ceglar et al., 2016

Seasonal climate forecasts in agriculture



Seasonal climate forecasts in agriculture

- Land surface initialization improves the skill of seasonal forecast over Europe for temperature, precipitation and extreme temperature indices (Prodhomme et al., 2015)
- Improvements robust among several prediction systems, especially in the Balkans region



Seasonal climate forecasts in agriculture

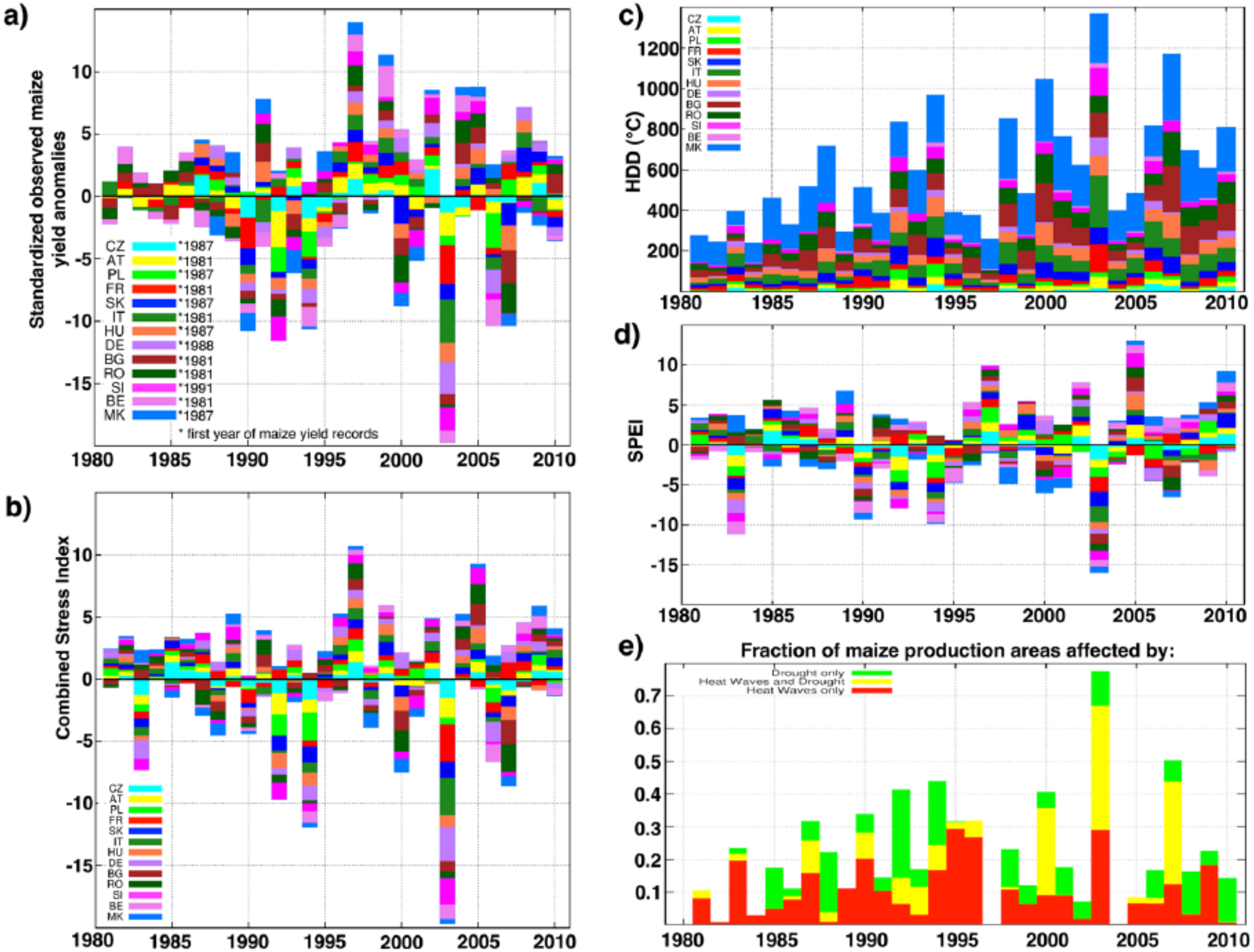
- A statistical model for maize yields
  - Capture the influence of drought/water stress and heat stress
    - **Drought stress:** Standardized precipitation-evapotranspiration index (SPEI) (Serrano et al., 2013)
    - **Hot days index**: accumulation of air temperatures above 30 °C

$$Y_t^{std,*} = a \times SPEI_{opt,t}^{*} + b \times HDD_{JJA,t}^{std,*} + \varepsilon_t = CSI_t + \varepsilon_t$$

    - Yield anomalies were obtained using the LOESS de-trending
    - Regression coefficients *a* and *b* were obtained usign the Tikhonov regularization (*ridge regression*)
    - Validation measures of derived statistical models: relative root mean square error (RRMSE), Q^2

$$Q^2 = 1 - \frac{\sum_{t=1}^{M} (\hat{y}_t^{(-t)} - y_t)^2}{\sum_{t=1}^{M} (y_t - y_{mean})^2},$$

Seasonal climate forecasts in agriculture



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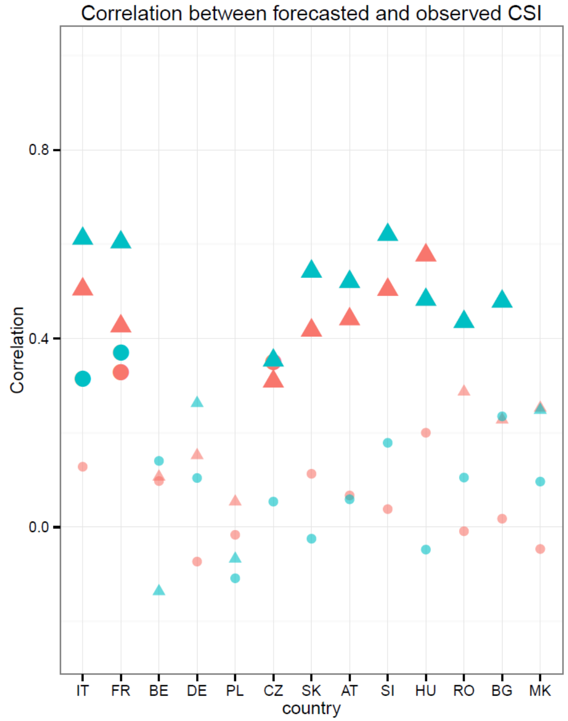
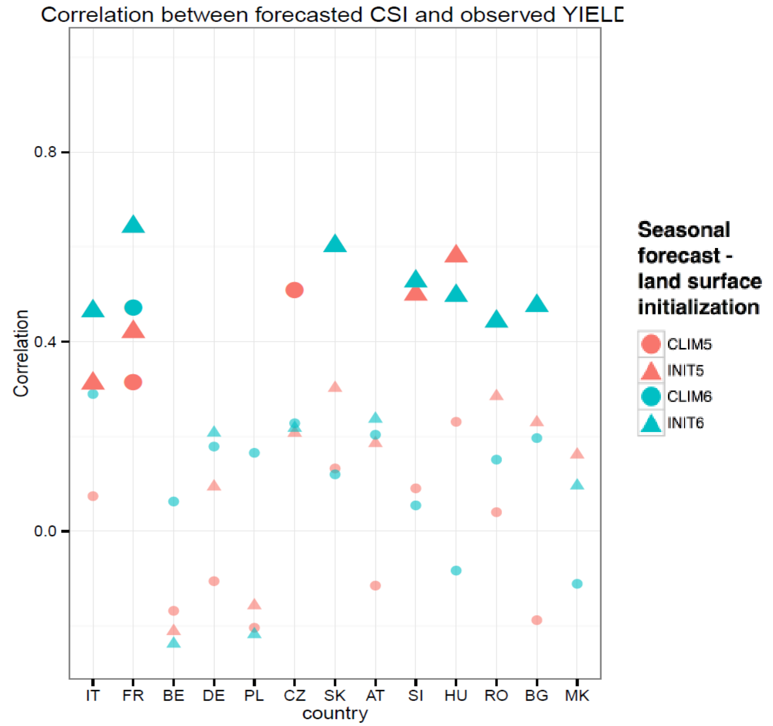
Seasonal climate forecasts in agriculture

- Seasonal forecast of CSI



Correlation between observed and forecast CSI



Correlation between observed and forecast maize yield anomalies

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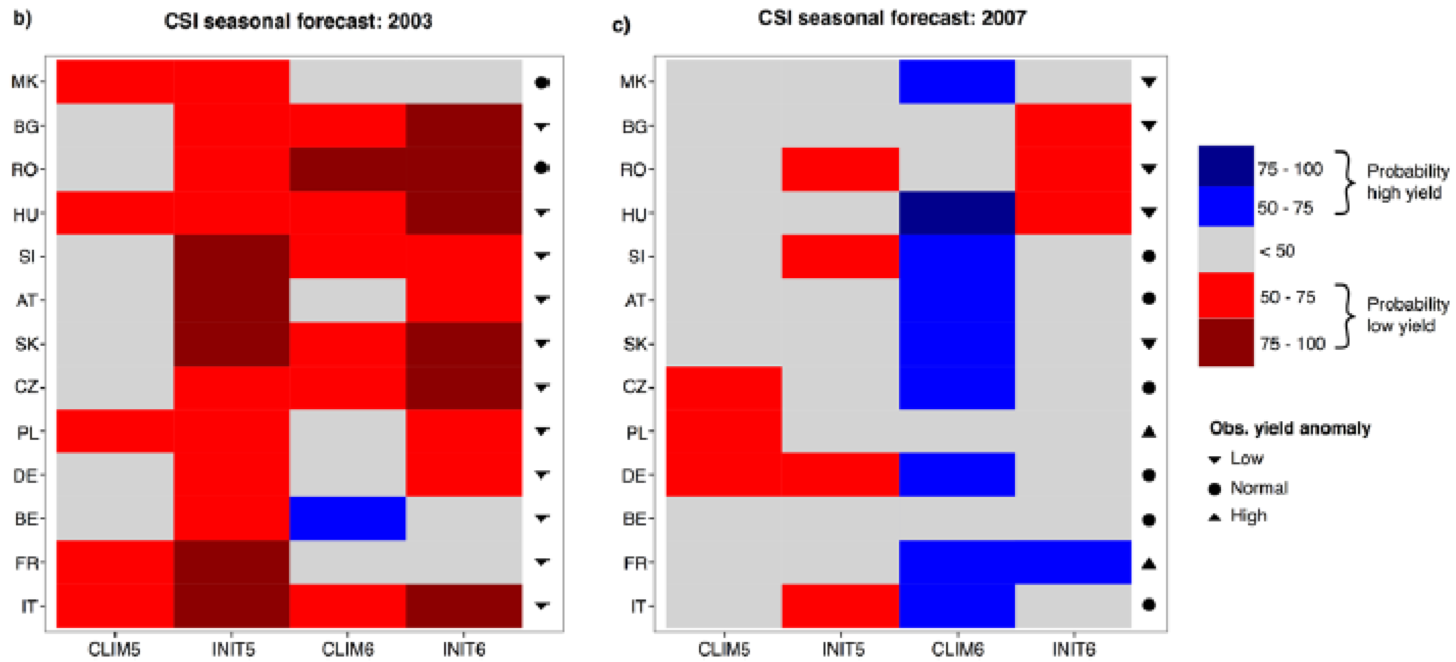
Seasonal climate forecasts in agriculture

- Case studies: 2003 and 2007
  - Forecast probabilities for low (CSI below 25th percentile) and high (CSI above 75th percentile) yielding events



Seasonal climate forecasts in agriculture

- Proper land surface initialisation of seasonal forecasts of grain maize yield anomalies can bring skill improvement in countries where climatological land surface initialisation fails
- Explore the predictability at earlier times (e.g. before sowing)
- Continue identifying relevant components of climate system that are predictable
- Process-based crop models vs. statistical methods
- Understand whether contrasting extremes across Europe might relate to predictable large-scale circulation patterns

Seasonal climate forecasts in agriculture

- Explore the possibilities of earth-system modelling approach
- Ensemble-based approach (crop and climate models)
- Bias-correction of seasonal climate forecasts on regional-to-local level
- Developments in technology, data access, and processing, may bring forecasting systems that operate at field level closer to those that operate at larger scales
- Evaluation of skillfull seasonal forecast on potential economic benefits for crop management depending on soil type, initial soil moisture, input costs, commodity price and risk attitude of farmers

Conclusions

- Operational crop monitoring and forecasting requires a multi source system
- Decision support system where the analyst plays a role
- Synergy and convergence of results as underlying analysis principle
- Crop yield monitoring and forecast challenges:
    - biophysical process modelling
    - Integration of seasonal forecast
    - Increase lead time of skillful forecasts
    - Agro-management (variety selection, field management, rotation patterns)
    - Better exploitation of earth observation data
- Better utilize information for farmer's benefits

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Thank you for your attention!

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Land-surface initialisation improves seasonal climate prediction skill for maize yield forecast

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Andrej Ceglar[1], Andrea Toreti[1], Chloe Prodhomme[2], Matteo Zampieri[1], Marco Turco[3] & Francisco J. Doblas-Reyes[2,4]

Seasonal crop yield forecasting represents an important source of information to maintain market stability, minimise socio-economic impacts of crop losses and guarantee humanitarian food assistance, while it fosters the use of climate information favouring adaptation strategies. As climate variability and extremes have significant influence on agricultural production, the early prediction of severe weather events and unfavourable conditions can contribute to the mitigation of adverse effects. Seasonal climate forecasts provide additional value for agricultural applications in several regions of the world. However, they currently play a very limited role in supporting agricultural decisions in Europe, mainly due to the poor skill of relevant surface variables. Here we show how a combined stress index (CSI), considering both drought and heat stress in summer, can predict maize yield in Europe and how land-surface initialised seasonal climate forecasts can be used to predict it. The CSI explains on average nearly 53% of the inter-annual maize yield variability under observed climate conditions and shows how concurrent heat stress and drought events have influenced recent yield anomalies. Seasonal climate forecast initialised with realistic land-surface achieves better (and marginally useful) skill in predicting the CSI than with climatological land-surface initialisation in south-eastern Europe, part of central Europe, France and Italy.

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In-season performance of European Union wheat forecasts during extreme impacts

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M. van der Velde, B. Baruth, A. Bussay, A. Ceglar, S. Garcia Condado, S. Karetsos, R. Lecerf, R. Lopez, A. Maiorano, L. Nisini, L. Seguini & M. van den Berg

Here we assess the quality and in-season development of European wheat (*Triticum spp.*) yield forecasts during low, medium, and high-yielding years. 440 forecasts were evaluated for 75 wheat forecast years from 1993–2013 for 25 European Union (EU) Member States. By July, years with median yields were accurately forecast with errors below ~2%. Yield forecasts in years with low yields were overestimated by ~10%, while yield forecasts in high-yielding years were underestimated by ~8%. Four-fifths of the lowest yields had a drought or hot driver, a third a wet driver, while a quarter had both. Forecast accuracy of high-yielding years improved gradually during the season, and drought-driven yield reductions were anticipated with lead times of ~2 months. Single, contrasting successive in-season, as well as spatially distant dry and wet extreme synoptic weather systems affected multiple-countries in 2003, '06, '07, '11 and 12', leading to wheat losses up to 8.1 Mt (>40% of total EU loss). In these years, June forecasts (~ 1-month lead-time) underestimated these impacts by 10.4 to 78.4%. To cope with increasingly unprecedented impacts, near-real-time information fusion needs to underpin operational crop yield forecasting to benefit from improved crop modelling, more detailed and frequent earth observations, and faster computation.

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Linking crop yield anomalies to large-scale atmospheric circulation in Europe

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ABSTRACT

Understanding the effects of climate variability and extremes on crop growth and development represents a necessary step to assess the resilience of agricultural systems to changing climate conditions. This study investigates the links between the large-scale atmospheric circulation and crop yields in Europe, providing the basis to develop seasonal crop yield forecasting and thus enabling a more effective and dynamic adaptation to climate variability and change. Four dominant modes of large-scale atmospheric variability have been used: North Atlantic Oscillation, Eastern Atlantic, Scandinavian and Eastern Atlantic-Western Russia patterns. Large-scale atmospheric circulation explains on average 43% of inter-annual winter wheat yield variability, ranging between 20% and 70% across countries. As for grain maize, the average explained variability is 38%, ranging between 20% and 58%. Spatially, the skill of the developed statistical models strongly depends on the large-scale atmospheric variability impact on weather at the regional level, especially during the most sensitive growth stages of flowering and grain filling. Our results also suggest that preceding atmospheric conditions might provide an important source of predictability especially for maize yields in south-eastern Europe. Since the seasonal predictability of large-scale atmospheric patterns is generally higher than the one of surface weather variables (e.g. precipitation) in Europe, seasonal crop yield prediction could benefit from the integration of derived statistical models exploiting the dynamical seasonal forecast of large-scale atmospheric circulation.

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