MCYFS - MARS Crop Yield Forecasting System

Resources and opportunities for pest risk assessment

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Content

- MARS crop yield forecasting system
  - Meteorological infrastructure
  - Crop model infrastructure
  - Remote Sensing infrastructure
  - Statistical infrastructure

- Pest risk assessment support
  - Collaboration with EFSA
  - ClimPest
  - MYMICS
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Crop monitoring in Europe since 20 years
MARS CROP YIELD FORECASTING SYSTEM - MCYFS

Regulation 78/200

ensure agro-economic monitoring of agricultural land and of the condition of crops, to enable estimates to be made, in particular as regards yields and agricultural production;

- CROP GROWTH MONITORING SYSTEM - CGMS

Weather monitoring

Crop growth simulation
WOFOST / WARM
CGMS or BIOMA engine

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

Yield forecasting

Vegetation monitoring (Remote Sensing)

CGMS database

promote access to the estimates referred to in point

- CROP MONITORING BULLETINS, WEB TOOLS

ensure technological follow-up of the agro-meteorological system.

- SW improvement and development, technical supervision of contractors
YIELD FORECASTS

The approach is straightforward: the final crop yield is a function of

\[ \text{crop yield} = f(\text{meteo impact on crops, crop growth simulated parameters, satellite observations on crop vegetation, time trend}) \]

...but the system to realize it is sophisticated and challenging
European meteorological infrastructure

Electronic data from: ECMWF, Remote Sensing, near real time observations - Meteorological satellites

Daily and long term average values
Station data – ca. 3000 daily stations reporting
Near real time observations – long term time series

Model data from ECMWF
ERA interim building the long term archive (1989 – April 2011)
ERA deterministic and probabilistic forecasts for NRT observations

Remote Sensing observations – Meteorological satellites
Near real time observations

Information extraction over space and time (single values – cumulative)
Time profile analysis
Probability analysis
Difference analysis
Rank analysis

Expert knowledge
Downscaling of coarser grids to final grid size
Extraction of input data for the model infrastructure
Extraction of input data for the RS infrastructure

Quantitative & qualitative reporting

*weighted means according to the presence of crops / arable land within the unit of interest
Active station net

Weather stations reporting in near real time to the MARS meteorological infrastructure for the main meteorological variables

Archive data since 1933, interpolated to the MARS grid since 1975

Blue dot: reliable stations with more than 80 % of the time reporting

Red dot: all stations in the system
Interpolation is used to convert irregular distributed station data to regular distributed data (25 km * 25 km grid) with different methodologies according to the parameter.
RAINFALL
Cumulated values

from: 01 June 2012
to: 30 June 2012

Deviation:
Year of interest - LTA

Unit: %
- >= -100 - < -80
- >= -80 - < -50
- >= -50 - < -30
- >= -30 - < -10
- >= -10 - < 10
- >= 10 - < 30
- >= 30 - < 50
- >= 50 - < 80
- >= 80 - < 100
- >= 100

11/07/2012
resolution: 25x25 km

(c) European Union 2012.
source: Joint Research Centre
Processed by: ALTERRA consortium
TEMPERATURE SUM

from: 01 June 2012
to: 30 June 2012

Deviation:
Year of interest - LTA
Base temperature: 0

Unit: degree days (Celsius)

- >= 40
- >= 30 - < 40
- >= 20 - < 30
- >= 10 - < 20
- >= 5 - < 10
- >= -5 - < 5
- >= -10 - < -5
- >= -20 - < -10
- >= -30 - < -20
- >= -40 - < -30
- < -40

11/07/2012
resolution: 25x25 km

(c) European Union 2012,
source: Joint Research Centre
Processed by: ALterra consortium
LONGEST HEAT WAVE
>=2 consecutive days where Tmax>30°C

from: 01 June 2012
to: 30 June 2012

Year of interest (YOI)

Unit: days
- 0
- 1 - 3
- 4 - 5
- 6 - 10
- >= 11

11/07/2012
resolution: 25x25 km
MINIMUM DAILY TEMPERATURE AGRICULTURAL AREAS

Averaged values

from: 01 February 2012
to: 29 February 2012

Deviation:
Year of interest - LTA

Unit: degrees Celsius

3 - 4
>0 - 2
0
-2 - < 0
-4 - -3
-6 - -5
-8 - -7
<-8

15/10/2012
resolution: NUTS Level 2

(c) European Union 2012,
source: Joint Research Centre
Processed by: ALTERRA consortium
Aggregated results over time

**Hessen (DE)**
Cumulated active temperatures above 0°C

**Mykolayivs'ka (Ukraine)**
Maximum daily temperature

**Ireland (IE)**
Average Global radiation Period: 01/04 - 15/07

**Zapadne Slovensko (SK)**
Cumulated ET0 and Climatic Water Balance

**Picardie (FR)**
Rainfall

**Deutschland**
Rainfall

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26 May 2014
Meteorological information combined with phenological stages

- excess of rain at sowing
- frosts at emergence
- droughts during vegetative growth
- dry spells at grain filling
- heath stresses before maturity

are reducing factors of plant productions and are taken into account by indicators
LONGEST HEAT WAVE AROUND RIPENING GRAIN MAIZE

>=2 consecutive days where Tmax>30°C

Deviation:

Year of interest - LTA
Year of interest: 2012
Offset (days): -11
Duration (days): 21

Unit: no. of events
- <= -20
- > -20 - <= -15
- > -15 - <= -10
- > -10 - <= -5
- > -5 - <= 0
- > 0 - <= 5
- > 5 - <= 10
- > 10 - <= 15
- > 15 - <= 20
- > 20

15/10/2012
resolution: 25x25 km

(c) European Union 2012,
source: Joint Research Centre
Processed by: ALTERRA consortium
European remote sensing infrastructure

European Remote Sensing Infrastructure
Daily, 10- daily, cumulative and long term average values

- SPOT – VEGETATION, NOAA-AVHRR, METOP
  Daily coverage at 1 km resolution
- MODIS TERRA
  10 daily coverage at 250 m resolution

Time profile analysis
Cumulative analysis
Difference analysis
Scenario analysis
Cluster analysis

Information extraction over space and time
as independent analysis and for the
statistical infrastructure

Expert Knowledge
Geometric correction,
Atmospheric correction
Compositing, interpolation, smoothing

Expert Knowledge
Retrieval spectral vegetation indices
Retrieval biophysical variables such as fAPAR
Extraction of input data for the model infrastructure

Quantitative & qualitative reporting

*weighted means according to the presence of crops/ arable land within the unit of interest
Remote Sensing contributions

Approaches followed:

- Independent analysis for crops and pastures - qualitative
- Independent analysis for crops – quantitative
- Merged analysis with meteo and crop simulation results – quantitative
**Sensor**
- MSG since 2005
- NOAA AVHRR since 1981
- METOP AVHRR from 2008
- SPOT VGT since 1998
- MODIS TERRA since 2000

**Preprocessing**
- Pan-European Daily, 10- daily, monthly, long term average
  - original bands
  - atmospheric correction
  - geometric correction
  - quality flag
  - compositing (MVC, avg)
  - interpolation
  - smoothing

**Indicators**
- Land surface temp.
- Radiation (DSSF)
- Sunshine duration
- Snow cover
- NDVI
- fAPAR
- DMP

**Info extraction over space and time**
- Difference analysis
- Time profile analysis
- Cluster analysis
- Similarity analysis
- Rank analysis
- Probability analysis

**C- indicator**
- Weighted mean according to land use within the unit of interest

**Administrative unit**
- Agri-ecological zonation
- Grid (25 km * 25 km)
Seasonal cumulated NDVI
Current season data vs historical data
Current season data: 1st Oct 2009 - 30 Sep 2010
Historical data: 1 Oct - 30 Sep

Data source: MARS remote sensing database / SPOT-VGT
Pasture and forage mask based on Capri database
Smoothed fAPAR

Current year - LTA
from: 1 April 2012
to: 10 April 2012
SPOT - VEGETATION (P)

Relative Differences [%]
- ≤ 25
- 24.8 - 10
- 9.9 - 10
- 10.1 - 25
- > 25

Cloud
Snow

Mask: Arable land mask based on CLC 2000 / Snow mask based on MSG - SEVIRI data
Data source: MARS remote sensing database / SPOT - VGT

Lorraine (FR)

Andalucía (ES)
Remote sensing approach to quantitative yield estimation

Crop yields related to cumulated fAPAR at regional / national level

Assumptions:

- The inter-annual *variability of* crop yield can be *explained by* crop photosynthetic activity along the season (water limited areas)
- The analysis is valid for *predominant crops* (typ. wheat/barley)
- Statistically-based (*reliable yield statistics are required*)
- *Crop acreage* is, more or less, *stable* (winter Vs summer cereals)

Integration period is optimized through a *regression between yield* figures and *fAPAR* with historical data
Some examples (1999-2011):

Morocco (Wheat)

Ukraine (Wheat)
Crop models are complex groups of algorithms that simulate crop growth: total biomass produced, grain biomass, etc. They use meteorological data as input as well as soil information and management data to account for the effects of changes in soil water content and crop management.
Crop simulation

The crop simulation module of the MCYFS integrates the effect of weather, soil and crop characteristics on crop growth assuming that the influence of other factors like farm management and socio-economic factors is constant.

The hart of the module consists of the WOFOST model which simulates crop development. These results are analyzed to identify abnormal situations and are used as input for the yield forecasting module.
Crop model infrastructure

Input data

Static data
- Crop parameters
- Soil parameters
- Administrative units

Meteorological infrastructure
- Observed interpolated weather data
- Downscaled forecast data

Remote sensing infrastructure
- Radiation
- NDVI, fAPAR

Crop growth models in CGMS
- WOFOST
- LINGRA
- WARM

Pan-European 10-daily long term average AGRO-METEO DB

Crop growth simulation

Water limited and potential per crop:
- Above ground biomass
- Storage organs
- Leaf area index
- Development stage
- Relative soil moisture
- Crop water requirements
- Crop water consumption

Simulated crops
- Wheat, Barley
- Maize, Rice, Sunflower
- Rapeseed, Sugar Beet
- Potato, Field Beans
- Pastures

Indicators

Info extraction over space and time

Difference analysis
- Time profile analysis
- Similarity analysis
- Rank analysis

C- indicator
- Weighted mean according to land use within the unit of interest

Ingestion into statistical infrastructure

Meteorological events in relation to crop development stage

EMILIA-ROMAGNA (IT)

Relative Soil Moisture of Wheat

26 May 2014
Outputs from the crop models

CLIMATIC WATER BALANCE
GRAIN MAIZE
Cumulated values
from: 01 June 2012
to: 28 August 2012

Deviation:
Year of interest - LTA

Units: mm
- < -150
- >= -150 - < -75
- >= -75 - < -25
- >= -25 - < 25
- >= 25 - < 75
- >= 75 - < 150
- >= 150

© European Union, data source: JRC MARS Crop Yield Forecasting System
© EuroGeographics for the administrative boundaries
Grain maize mask: "Global harvested areas and yield maps" produced by SAGE (University of Wisconsin-Madison)
Outputs from the crop models

Ellada
Crop development stage of Sugar beets - EU27

Eszak-Alfold (HU)
Relative soil moisture of Grain maize

Mecklenburg-Vorpommern (DE)
Water limited leaf area index of Winter rapeseed

Castilla-La Mancha (ES)
Water limited above ground biomass of Spring barley

Mykolyayvis'ka (Ukraine)
Water limited storage organs of Winter wheat

Severen Tsentralen (BG)
Water limited storage organs of Grain maize

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The libraries currently available

Weather libraries
- AirTemperature, EvapoTranspiration, LeafWetness
- Climate indices
- Weather Generation (ClimGen, CLIMAK)

Stresses
Abiotic
- Heat damage
- Frost kill
- Rice cold shocks
- Lodging

Biotic
- Generic air-borne diseases
- Generic soil-borne diseases
- CornBorer simulator

Plant libraries
- Generic crop Simulation (CropSyst, WOFOST)
- Pasture (STIC)
- Rice (WARM)
- SugarCane (CANEGRO)

Agriculture management
- Rule based modelling

Soil libraries
- Soil water runoff and erosion
- Soil water redistribution (cascading, FiniteDifferences)
- Soil surface and profile temperature
- Soil Nitrogen
- Pedotransfer functions
This infrastructure integrates all the statistical methods, resources and information needed to forecast crop yields using the information provided by crop models, remote sensing and meteorological data.
**MCYFS statistical forecast principles**

**Classic regression approach**, focus relationship between a dependent variable—the yield—and one or more independent parameters related to climate/weather effects.

**Scenario analysis**, based on analogies between the contingent conditions and the past, investigating years that behave similarly with respect to selected events and reporting their measured effects on the actual state in order to predict final consequences.

The yield "predictors" consist in any variables related to crop yield at harvest time, belonging to and weighting one of the following aspects: meteorological impact evaluation (minimum or maximum temperature, rain, radiation level, etc.), crop status assessment (e.g. soil moisture, development stage) and crop growth expectations (e.g. potential yield biomass, potential yield storage).
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Collaboration with European Food Safety Authority (EFSA)

- Provision of climate data (e.g. air temperature, precipitation) for selected locations in Europe

- Provision of tailored environmental data (e.g. simulated soil temperatures at different soil depths for a given crop)

- CLIMPEST application: “Model framework for the assessment of EU climatic suitability for the establishment of organisms harmful to plants and plant products”

- Contribution to scientific opinions (e.g. Phytophthora fragariae, Phyllosticta citricarpa)
Simulation of soil temperatures over Europe

Andrija Ceglar, Davide Fumagalli, Stefan Niemeier

Institute for Environment and Sustainability
Monitoring Agricultural Resources Unit

2013

Simulation of relative humidity over southern Europe

Andrija Ceglar, Iacopo Cerrani, Stefan Niemeier

Institute for Environment and Sustainability
Monitoring Agricultural Resources Unit

2013
Surface soil temperature
EXTERNAL SCIENTIFIC REPORT

Model framework for the assessment of EU climatic suitability for the establishment of organisms harmful to plants and plant products – CLIMPEST project (SLA/EFSA-JRC/2008/PLH/01)

Marcello Donatelli (JRC and CRA), Simone Bregaglio (JRC and Univ. Milan), Davide Fumagalli (JRC), Bettina Baruth (JRC)

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ABSTRACT

In the frame of the SLA a model framework was developed named Climpest allowing the assessment of EU climatic suitability for the establishment of organisms harmful to plants and plant products and more specifically to estimate the weather suitability for potential infection by the citrus pathogen *Corynespora ciclamina* (common name Citrus Black Spot - CBS). The model framework Climpest can be re-used for other plant diseases and pests and it contains the following modelling solutions: ClimIndices (calculation of climatic indices) and Potential Infection Model (calculation of the potential infections of fungal fungal pathogens on plants). The software has access to a remote database containing historical series of daily weather data with Europe spatial coverage on a 25 x 25 grid. Climate change scenarios for 2020 and 2050 are also made available related to the emission scenarios A1B and B1. The software was designed to be extended automatically by third parties with diverse modelling solutions, other than the ones provided in this first version.

KEY WORDS

Model framework, potential infection model, BioMa, meteorological databases, climate change scenarios

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R² = 0.38 (no trend)

**Indicators:**
- DVS
- LAI
- WL biomass
- WL LAI

R² = 0.81 (no trend)

**Indicators:**
- Black rust-biomass
- Black rust infection events
- DVS
- WL biomass
MIMYCS project “Maize Infection and Mycotoxin Contamination Simulator”

- Development of a process-based phenological model for the **two main insect borers in maize**: Ostrinia nubilalis and Sesamia nonagrioides
- Development of a process-based model to simulate **toxigenic fungi development inside maize grain** and mycotoxin synthesis
- Development of an original model for the simulation of **moisture content in maize**;
- Simulations at EU scale **mycotoxin contamination in maize grain** in different climatic, environmental and agro-management situations

Collaboration Agreement with **Syngenta Seeds SpA**
Calibration and validation for the Po Valley, northern Italy
Changes 2050 - 2000

Figure 26. Difference in the estimated contamination of maize grain kernels by fumonisins (25a), deoxynivalenol (25b), and aflatoxins (25c)

Figure 26a – Fumonisins by Fusarium verticillioides

Figure 26b – Deoxynivalenol by Fusarium graminearum

Figure 26c – Aflatoxins by Aspergillus flavus
Thank you for your attention

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To know more?
Detailed information of the components of the MARS Crop Yield Forecasting System can be found in our webpages. The main product of the crop monitoring and yield forecasting activities are the MARS Bulletins regularly published on our web pages.  

For a link into our online MARS Viewer with many near real-time information on crop weather conditions, please visit the MARSOP pages.  
http://www.marsop.info/