The WOFOST model, its principles, implementation, main parameters and examples of use

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Origin and initial objectives MARS

- 1988 start
- MARS = Monitoring Agriculture with Remote Sensing
  - Leadership: EC-JRC in Ispra, Italy
  - Customers: EC-DG-Agri and Eurostat
  - Developers: JRC and contractors (research institutes)
- **Task**: develop a system to estimate regional crop production for Europe
- **Required information**: independent, unbiased and timely estimates of the production of major European crops
  - per EU country
  - crop-specific
  - early within season
  - cost-effective
Target information and reference data

Crop production estimates = CROP YIELDS * ACREAGE
- Early forecast crop yields
- Precise Crop Area Estimates

Yield estimates in MARS 199ies from
- MARS Action 2 AVHRR, and Action 4 rapid estimates
- MARS Action 3 meteo, agromet models,
  - Data types: weather, soil, land use, elevation
  - Data on current year and in historic archive, daily to 10-daily
  - Full spatial coverage over Europe,
  - Resolution: ideal elementary reference is single crop field (crop, soil, weather)

See http://www.marsop.info/marsop3/
MARS Action 3 Agromet models

**Goal:** quantification of inter-annual yield variability per crop over regions and countries through objective, science-based, reproducible results

**Assumptions on yield of annual field crops:**
- Weather is main driving factor
- A priori choice for semi-deterministic crop model to integrate effects of many meteo data
- Thus many meteo data are concentrated into few simulated yield data
- Output of crop model is used as predictor of regional crop yield in a statistical model

(Note: a stand-alone statistical agromet model cannot deal with multitude of meteo-data)
Agromet model  CGMS : three levels

The MARS Action 3 resulted in the Crop Growth Monitoring System (CGMS) combining

- Level 1  Weather monitoring
- Level 2  Crop monitoring by simulation (WOFOST)
- Level 3  Yield forecast by regression

Note: Vegetation monitoring based on Low Res NOAA-AVHRR and SPOT Vegetation are separate processing lines
The CGMS Crop Model, why WOFOST?
Choice of model for regional yield forecasting

Original aim of crop models
- Integrate knowledge on plant growth processes
- Test hypothesis by mathematical reproduction of experiments in laboratory or trial fields
- Explain crop responses under a range of conditions (ecological, management), covered by experiments
- Explore crop responses under a range of conditions not yet covered by experiments

- Detailed multi-parameter complex models may be over-sensitive to variation in input
- Simple summary models may be insensitive to variation in input

- For practical applications a balanced level of complexity and sensitivity must be found, while taking account of data availability.
Wanted: a semi-deterministic crop model

Crop modeling approach according to De Wit

Original idea: Photosynthesis of leaf canopies (de Wit 1965)

- Biophysical crop system, driven by light interception and photosynthesis
- Dynamic
- Hierarchical
- State-variable based
- Explanatory
- Deterministic
- Generic, universal
Crop modelling approach according to De Wit

- System is a simplified description of reality: a homogeneous crop field, with defined thematic boundaries, internal characteristics and external driving variables.

- Dynamic: Rates of change per unit time as opposed to static. Integration over time.

- Hierarchical
  - Within a system: Cells – organs – plants- crop
  - Sequence in system complexity defined by a succession of theoretical production situations: potential, water-limited, nutrient-limited,

- State-variable based: Starting from gives initial state, each state is updated each time step, where State = previous state + rate of change. Most basic crop states are expressed in dry weight of living biomass and crop development stage (crop age).

- Explanatory: explicit quantitative description of bio-physical processes leading to change in system state, by means of mathematical equations.

- Deterministic: a given crop responds according to the rules, defined in the model (apparent absence of uncertainty).

- The most basic processes are generic and universally valid for all crops and all crop varieties (“It is green and it grows”).
The model crop: it is green and it grows

- Differences in crop growth processes between crops are due to different model parameter values.

- A cereal crop is the basic reference for an annual field crop in the crop model.

- Root crops, legumes, vegetables and grasses are forced into the basic cereal model.

In many crop models: a crop is a tube conveying water from the soil to the atmosphere
Production ecological principles of yield levels

Van Ittersum and Rabbinge, 1997

**Defining factors**
- CO₂
- Radiation
- Temperature
- Crop features

**Limiting factors**
- Water
- Nutrients
- Weeds
- Pests
- Diseases
- Pollutants

**Production level (t/ha)**

**Production situation**

- Potential
- Water- and nutrient limited
  - Attainable yield
- Actual yield

Van Ittersum and Rabbinge, 1997
Definitions Production Situations

- **Potential yield – yield potential:**
  - the yield of crop (cultivar/hybrid) when grown under defined conditions (CO2, T, radiation) without growth limitations from water, nutrients, pests or diseases

- **Water-limited/nutrient-limited yield:**
  - the yield of a crop (cultivar/hybrid) when grown with water limitation or with one or more nutrient deficiencies as the primary growth limiting factors

- **Actual yield:**
  - the measured yield from a field or farm, or the estimated average yield for a region or nation as reported in national and international databases.

How estimated:
- through a model, experiments, best practice or census data

Van Ittersum and Rabbinge, 1997; Lobell et al., 2009
WORld FOod Studies crop simulation model, of potential and water-limited production situations since 1986
SUCROS-family models (including WOFOST) modeling scheme: state-driver-rate
(Simple and Universal CROp growth Simulator)
SUCROS (WOFOST)-modeling scheme (drivers, processes, state, rate)