PERUN: THE SYSTEM FOR SEASONAL CROP YIELD FORECASTING BASED ON THE CROP MODEL AND WEATHER GENERATOR

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www.ufa.cas.cz/dub/crop/crop.htm

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Previous research (since 1995):

**experimental crop sites:** three locations in the Czech Republic
[Žabčice, Domanínek, Kroměříž]
~ source of data for crop model validation

**crop models:** MACROS, WOFOST, CERES (Maize, Wheat, Barley), SHOOTGRO

**weather generator:** Met&Roll (PREC, SRAD, TMAX, TMIN, .... wind, humidity)

**climate change impact studies:**
- **climate change scenarios** = incremental scenarios, GCM-based scenarios, climate sensitivity scenarios)
- **method** = direct modification approach; weather generator approach

[see [www.ufa.cas.cz/dub/dub.htm](http://www.ufa.cas.cz/dub/dub.htm) for the references]
PERUN
(development of the software started last year)

PERUN: system for crop model simulations under various meteorological conditions

tasks to be solved by PERUN/
• crop yield forecasting
• climate change/sensitivity impact analysis

requirements:
• runs under Windows
• user friendly & robust
• comprises all parts of the process:
  □ preparing input parameters for the crop model simulation (with a stress on the weather data representing various climate conditions or a short/long range weather forecast)
  □ launching the crop model simulation
  □ statistical and graphical analysis of the crop model output

components:

1) WOFOST crop model (v. 7.1.1.; provided by Alterra Wageningen)
   new: Makkink formula for evapotranspiration was implemented

2) Met&Roll weather generator (Dubrovs'ky, 1997)
   new: - wind and humidity generated by nearest neighb. resampling
       - synthetic series follows with the observed series at any date

3) user interface
   - input for WOFOST (crop, soil and water, start/end of simulation, production levels, fertilisers, ...)
   - launching the simulation [construction of the batch file (GO.BAT) and starting it, ....]
   - statistical and graphical processing of the simulation output
assumptions:
- crop model is validated
- weather generator is validated

climate change impact analysis

general scheme:
1. crop model run with weather series representing present climate
2. crop model run with weather series representing changed climate
3. comparison of the outputs from the two simulations

weather / climate options:
- type of the weather series (2 approaches):
  a) direct modification approach (DM): observed series for present climate, directly modified weather series for changed climate (according to the climate change scenario)
  b) weather generator approach (WG): synthetic series for both climates (parameters of WG are derived from the observed series and modified according to the climate change scenario)
    - in case the Penman formula is used, the wind and humidity is generated using nearest neighbours resampling
    - selected parameters of the generator may be set (order of the Markov chain, effectiveness of the resampling procedure, ...)

- climate change scenario (may include changes in variabilities and in other WG parameters in the case of WG approach)

- length of the weather series:
  a) less then the length of the observed series (DM approach)
  b) arbitrary length (WG approach)
seasonal crop yield forecasting
seasonal crop yield forecasting

input data to crop model

a) non-weather data: info about crop, soil and hydrology, water regime; start/end of simulation, nutrients, ... (as in WCC)

b) weather data:
   - station
   - day D₀ (observed data till D₀ − 1, synthetic since D₀;
   - weather forecast table (weather series are postprocessed to fit the weather forecast table forecast)
   - observed or synthetic series (obs. series is used for validation)
   - formula for evapotranspiration: Makkink or Penman

c) N = number of re-runs (new weather data are generated for each simulation; other input data are always the same)

weather forecast table (3 methods)

1) absolute values of the \( n \)-days averages \([n \text{ is optional}]\)

   \[
   \begin{array}{cccccc}
   \text{JD-from} & \text{JD-to} & \text{TMAX} & \text{TMIN} & \text{PREC} & \text{TMAX} & \text{TMIN} & \text{PREC} \\
   99121 & 99130 & 17 & 6 & 30 & 2 & 2 & 10 \\
   99131 & 99140 & 14 & 4 & 60 & 3 & 3 & 20 \\
   99141 & 99150 & 21 & 10 & 10 & 4 & 4 & 10 \\
   \end{array}
   \]

2) increments to existing series

3) increments with respect to the long-term means

   \[
   \begin{array}{cccccc}
   \text{JD-from} & \text{JD-to} & \text{TMAX} & \text{TMIN} & \text{PREC} & \text{TMAX} & \text{TMIN} & \text{PREC} \\
   99121 & 99130 & -1 & -1 & 1 & 0 & 0 & 0 \\
   99131 & 99140 & -1 & -1 & 1 & 0 & 0 & 0 \\
   99141 & 99150 & -1 & -1 & 1 & 0 & 0 & 0 \\
   \end{array}
   \]
validation of WOFOST

a) spring barley - Hana; site = Domanínek, Czechia; 1990-2000 (11 y)

b) winter wheat (Akcent); site = Domanínek, Czechia; 1985-97 (14 y)
Crop yield forecasting at various days of the year

♦ forecast <avg±std> is based on 30 simulations
♦ input weather data for each simulation =
  [obs. weather till D−1] + [synt. weather since D; without forecast!]

a) the good fit between model and observation

site = Domanínek, Czech Republic
crop = spring barley
year = 1999
emergency day = 122
maturity day = 225
observed yield = 4739 kg/ha
model yield = 4580 kg/ha (simulated with obs. weather series)
**b) the poor fit between model and observation**

- **site** = Domanínek, Czech Republic
- **crop** = spring barley
- **year** = 1996
- **emergency day** = 124
- **maturity day** = 232
- **observed yield** = 3956 kg/ha
- **model yield** = 5739 kg/ha (simulated with obs. weather series)

**task for future research:** to find **indicators** of the crop growth/development (measurable during the growing period) which could be used to correct the simulated characteristics, thereby allowing more precise crop yield forecast.
sensitivity of prognosed yields
to temperature and precipitation
(for various days of the year)

input weather data: [observed data till day 189] + [synthetic since 190]
target weather forecast period = day 190 - maturity

input weather data: [observed data till day 155] + [synthetic since 156]
target weather forecast period = day 156 - 185
**input weather data:** [observed data till day 119] + [synthetic since 120];
target weather forecast period = day 120 – 149

**input weather data:** synthetic weather series for the whole year
target weather forecast period = day 1 – 365
Conclusions

PERUN = system for
- probabilistic crop yield forecasting
- climate change/sensitivity analysis

validation of crop model WOFOST:
- not good (higher correlation between observed and model yields is required to make reliable crop yield forecast)
- not bad (input data for crop model were not perfect)

Penman formula performs slightly better than the Makkink's

future research:
to find *indicators* of the crop growth/development (measurable during the growing period) which could be used to correct the simulated characteristics, thereby allowing more precise crop yield forecast: