Drought Monitoring System for Agriculture in Austria
Project “AgroDroughtAustria-ADA”

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(6) National Drought Mitigation Center NDMC, USA
Pre – projects

GRAM: GIS-based Grassland simulation

CLIMSOIL: GIS-based soil temperature model
Original model concept (grassland)

Input weather data:
TMAX, TMIN, TAVG, SRAD, PREC, WIND, RH

Input soil data:
WILTING POINT, FIELD CAP, DEPTH OF THE PROFILE

Input crop data:
CUTTING DATES, NITROGEN FERTILIZATION

Soil water balance model:

S_W_B model outputs:
EFFECTIVE TEMPERATURE SUM,
EFFECTIVE SOLAR RADIATION SUM,
NUMBER OF SNOW DAYS

Gram: Grassland statistical model:
MULTIPLE REGRESSION VERSION
& NEURAL NETWORKS VERSION

Dry matter yield
(DAILY OR SEASONAL)
Water Balance Model according to FAO Paper No. 56

- Water Stress
  - Precipitation
  - Evapotranspiration
- Available Soil Water
  - Deep Percolation
  - Root Zone Depletion
- Water holding capacity (field capacity)
  - Surface runoff
  - Capillary rise
Simulated actual evapotranspiration of grassland on July 20th 2009 in 1x1 km spatial resolution.

Schaumberger, 2009
Simulated grassland biomass yields in 2003
Soil Temperature Model Scheme for GIS application

**Input of spatial data (1x1 km) from GIS**

Variable Parameters (daily):
- Air Temperatures: Mean, Maximum, Minimum
- Global Radiation
- Snow Cover
- Soil cover - biomass
- Albedo
- Actual evapotranspiration
- Soil water content (layer)
- Soil pore volume (layer)

Constant Parameters:
- Soil layer thickness (per layer)
- Soil - fraction of sand
- Soil - fraction of clay
- Annual mean temperature

**Soil temperature model calculation steps:**

1) Estimation of soil surface temperature
2) Estimation of soil heat conductivity and capacity per soil layer
3) Estimation of heat flux through soil layers (reduced number of steps, heat flux equation)
4) Consideration of soil water freezing/thawing
5) Estimation of daily temperature amplitude per soil layer

**Output parameters (1x1 km) from GIS**

Variable Parameters (per predefined soil layers, daily basis):
- Soil surface temperature (Max, Min)
- Mean, maximum and minimum temperatures
- Fraction of soil ice content
- Soil temperature sum (per soil layer)

Pest models, C/N balance model,...
Project CLIMSOIL: Soil Temperature Model in GIS

Soil Temperature in 2 cm
19.09.2009 [°C]
- 12.5 - 15.5
- > 15.5 - 17.0
- > 17.0 - 18.0
- > 18.0 - 19.0
- > 19.0 - 20.5

Data: ZAMG - MOI Austria Lambert
Layout: Andreas Schaumberger / Mai 2012
The aim of the ADA project (2013-2016) is to develop and test a crop specific drought monitoring and forecasting system for agriculture in Austria.

Objectives:

1) Establish a data base and develop methods for crop drought and heat stress and yield impact detection

2) Establish a forecasting approach modelling drought occurrence (10 days and seasonal) and GIS implementation

3) Adapt and validate soil water content calculation methods (SOILCLIM Model) and GIS implementation

4) Test the crop specific drought monitoring system for operational use
ADA – Work packages

WP 1
Data base
Data base on crop specific drought and heat vulnerability and impacts under Austrian and climate change conditions

WP 2
Monitoring methods
Adaptation, calibration and validation of existing methods to detect drought and drought impacts for arable crops and grassland

WP 3
Forecasting methods
Development of drought-specific forecasting products

WP 4
GIS implementation
Spatial Implementation of drought monitoring on the base of existing GIS with adaptations for Austrian agricultural land

WP 5
Test and Calibration
Test and evaluation of the drought monitoring system with stakeholder participation
Validation data base for simulated soil moisture – Available Soil Water Stations & Main Production Areas

21 Locations  69 plots  
17 grass land  48 arable land  4 forest  
Elevation  150 - 1912 m  
Measuring depths  5 – 300 cm  
Measurement period  1992 – ongoing  
Daily data - soil moisture  

Krammer, 2013
Soil water balance model (SOILCLIM) - evaluation

Example of the SoilClim model evaluation at the Hirschstetten site (top layer 0-40 cm).
Estimating drought impacts on crops

1) Development/implementation of crop phenology model (Kc model)

Methods: Crop model application under Austrian conditions

2) Development and test of drought and heat impacts on yield risk (indicator) and yield level (potential yield depletion)

Methods: Statistical analysis of crop yield data
Crops specific responses to drought/heat

1) Drought impacts:
Dominating effects on biomass accumulation (Photosynthesis rate depression), biomass partitioning and yield forming processes (i.e. corn filling)
(crop yields determined by vegetative development only: i.e. grassland, sugar beet, biomass crops)

2) Heat impacts:
(further forced by water stress conditions)
Dominating effects on phenology, corn filling and fertility (flowering period!)
especially crop yields determined by generative development:
Grain maize, cereals, ..)
**Crop Coefficient Model for ADA (Kc Factor)**

Reference Evapotranspiration (ET0) for December, January and February is a constant value of 0.2 mm.

Start of Growing Season (SGS): *First day of 5 consecutive days with daily mean temperatures above 5°C*

Start of Growing Season for Maize (SGS-M): *First day of 5 consecutive days with daily mean temperatures above 10°C*

Base temperature for calculation of degree day temperature sum (BT): 5 °C

Base temperature for calculation of degree day temperature sum for Maize (BT-M): 8 °C

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**Phenological model**

(to be used for evapotranspiration calculation and stress indicators)

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**Crop Coefficient Model for ADA (Kc Factor)**

<table>
<thead>
<tr>
<th>Culture</th>
<th>Initial (Evaporation)</th>
<th>Crop Development</th>
<th>Mid-Season</th>
<th>Late Season</th>
<th>End of Growing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entry of A</td>
<td>Entry of B</td>
<td>Entry of C</td>
<td>Entry of D</td>
<td>Entry of E</td>
</tr>
<tr>
<td></td>
<td>Kc</td>
<td>Time</td>
<td>Kc</td>
<td>Time (GDD)</td>
<td>Kc</td>
</tr>
<tr>
<td>Grassland (3-cut)</td>
<td>Will be done by LF1 Raumberg-Gumpenstein (according to Schaumberger, 2011)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>0.4</td>
<td>01.03.</td>
<td>0.4</td>
<td>SGS</td>
<td>1.2</td>
</tr>
<tr>
<td>Spring Barley</td>
<td>0.4</td>
<td>01.03.</td>
<td>0.4</td>
<td>SGS</td>
<td>1.2</td>
</tr>
<tr>
<td>Spring Maize</td>
<td>0.4</td>
<td>01.04.</td>
<td>0.4</td>
<td>SGS-M</td>
<td>1.2</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>0.4</td>
<td>01.04.</td>
<td>0.4</td>
<td>300</td>
<td>1.2</td>
</tr>
</tbody>
</table>

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Institut für Meteorologie | BOKU
Stress indicators

Impact of drought and heat on crop stress (risk indicators) and yield level (potential yield depletion)

A. Risk approaches (without crop specific vulnerability calibration)

1. a) General drought indicator (Soil water content in regard to the normal) and b) crop specific water stress factor (actual and accumulated) (linear increasing stress beyond 30% AWC depletion)

2. Heat stress factor (actual and accumulated)
   - number of days above 32°C
   - Duration above critical T:
     Accumulated hourly indicator for day N: \( (\sum(T_{hourly}-31.9)^2) \)

3. Heat stress x crop specific water stress factor
   (way of combination of ad 1+2; i.e. reduction of heat stress impact above 70% AWC)

B. Crop vulnerability approaches

1. Crop specific heat and drought stress risk at different phenological states
2. potential yield depletion
   (implementation of relative sensitivities in combination with crop phenology)

Calibration/validation with crop yield data
Central European **drought impacts** on Maize and Wheat (exp. yield statistics > 15 years)

Table 8. Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of dry days and observed MZ yield. No effect: 11 of 22; with effect: 7 of 22.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dstart</th>
<th>Dintensive</th>
<th>Dextreme</th>
<th>Dwextreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMJ</td>
<td>JJA</td>
<td>MAM</td>
<td>AMJ</td>
</tr>
<tr>
<td>Ziharec</td>
<td>0.59</td>
<td>0.10</td>
<td>0.65</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.76)</td>
<td>(0.03)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Podhajska</td>
<td>0.19</td>
<td>-0.42</td>
<td>0.26</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>(0.57)</td>
<td>(0.19)</td>
<td>(0.44)</td>
<td>(0.49)</td>
</tr>
</tbody>
</table>

Maize: June-August

Table 9. Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of dry days and observed WW yield. No effect: 27 of 49; with effect: 3 of 49.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dstart</th>
<th>Dintensive</th>
<th>Dextreme</th>
<th>Dwextreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMJ</td>
<td>MAM</td>
<td>AMJ</td>
<td>MAM</td>
</tr>
<tr>
<td>Gross-Enz.</td>
<td>-0.49</td>
<td>-0.41</td>
<td>-0.52</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.10)</td>
<td>(0.03)</td>
<td>(0.53)</td>
</tr>
<tr>
<td>RimskiSancevi</td>
<td>-0.22</td>
<td>-0.13</td>
<td>-0.32</td>
<td>-0.41</td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td>(0.54)</td>
<td>(0.12)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Ziharec</td>
<td>-0.37</td>
<td>-0.26</td>
<td>-0.31</td>
<td>-0.28</td>
</tr>
<tr>
<td></td>
<td>(0.213)</td>
<td>(0.39)</td>
<td>(0.30)</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Podhajska</td>
<td>-0.34</td>
<td>-0.38</td>
<td>-0.31</td>
<td>-0.17</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.16)</td>
<td>(0.26)</td>
<td>(0.54)</td>
</tr>
<tr>
<td>Belusa</td>
<td>-0.24</td>
<td>0.00</td>
<td>-0.38</td>
<td>-0.27</td>
</tr>
<tr>
<td></td>
<td>(0.37)</td>
<td>(1.00)</td>
<td>(0.14)</td>
<td>(0.31)</td>
</tr>
</tbody>
</table>

WW: yes (March-June)

Lalic et al., 2014
Central European **heat impacts** on Maize and Wheat (exp. yield statistics > 15 years)

**Table 6.** Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of days with extreme temperatures and observed MZ yield. No effect: 17 of 30; with effect: 6 of 30.

<table>
<thead>
<tr>
<th>Location</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SumD</td>
<td>FrostD</td>
<td>TropD</td>
<td>SumD</td>
<td>TropD</td>
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<tr>
<td>DubrovčakLijevi</td>
<td>0.03</td>
<td>-0.43</td>
<td>-0.31</td>
<td>-0.34</td>
<td>-0.07</td>
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<tr>
<td></td>
<td>(0.93)</td>
<td>(0.18)</td>
<td>(0.35)</td>
<td>(0.30)</td>
<td>(0.83)</td>
</tr>
<tr>
<td>Ziharec</td>
<td>0.09</td>
<td>0.24</td>
<td>0.51</td>
<td>0.38</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td>(0.47)</td>
<td>(0.10)</td>
<td>(0.24)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>Podhajska</td>
<td>-0.47</td>
<td>0.08</td>
<td>0.00</td>
<td>-0.20</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(0.81)</td>
<td>(1.00)</td>
<td>(0.55)</td>
<td>(0.57)</td>
</tr>
</tbody>
</table>

**Table 7.** Correlation coefficients and p values (in brackets, underlined values are significant) between AMI describing number of days with extreme temperatures and observed WW yield. No effect: 41 of 63; with effect: 2 of 63.

<table>
<thead>
<tr>
<th>Location</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FrostD</td>
<td>FreezeD</td>
<td>FrostD</td>
<td>FreezeD</td>
<td>FrostD</td>
<td>FreezeD</td>
</tr>
<tr>
<td>Gross-Enz.</td>
<td>-0.14</td>
<td>-0.14</td>
<td>-0.43</td>
<td>-0.43</td>
<td>-0.27</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>(0.59)</td>
<td>(0.59)</td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.29)</td>
<td>(0.59)</td>
</tr>
<tr>
<td>RimskiSancevi</td>
<td>-0.27</td>
<td>-0.10</td>
<td>-0.42</td>
<td>-0.44</td>
<td>-0.03</td>
<td>-0.22</td>
</tr>
<tr>
<td></td>
<td>(0.20)</td>
<td>(0.64)</td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.88)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>Ziharec</td>
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<td>-0.44</td>
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<td>-0.34</td>
<td>-0.33</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.13)</td>
<td>(0.69)</td>
<td>(0.25)</td>
<td>(0.27)</td>
<td>(0.84)</td>
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<tr>
<td>Podhajska</td>
<td>-0.23</td>
<td>-0.32</td>
<td>-0.15</td>
<td>-0.08</td>
<td>-0.02</td>
<td>-0.23</td>
</tr>
<tr>
<td></td>
<td>(0.40)</td>
<td>(0.24)</td>
<td>(0.59)</td>
<td>(0.77)</td>
<td>(0.94)</td>
<td>(0.40)</td>
</tr>
<tr>
<td>Belusa</td>
<td>0.11</td>
<td>-0.23</td>
<td>-0.30</td>
<td>-0.28</td>
<td>-0.21</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td>(0.68)</td>
<td>(0.39)</td>
<td>(0.25)</td>
<td>(0.29)</td>
<td>(0.43)</td>
<td>(0.91)</td>
</tr>
</tbody>
</table>

Maize: yes (July-August)

WW: yes (May-June)

Lalic et al., 2014
Results (see next presentations for more details)

- Simple crop-soil water balance approach satisfactory validated
- Significant relationships of drought/heat events for selected main crops
- Crops differ on heat and drought responses under conditions in Austria
- Combination of drought/heat indices is the best approach to address crop specific responses
- General and crop specific drought/heat monitoring and forecast implemented in GIS
- Operational setup of the system demonstrated
1. The GIS model enables near time monitoring and forecast of crop growing conditions and risks (water balance, biomass development, drought and heat stress and yield depletion) for agricultural land in Austria in a high spatial resolution (0.5 x 0.5km) and daily time step.

2. High application potential for spatial mapping/forecast of additional weather related indicators (water footprint, other crop risks from adverse weather conditions).

3. Extended application potentials by including remote sensing products.


5. International cooperation for drought/heat monitoring system increases efficiency and robustness of system performance.
Problems and challenges

1. Operational implementation requests permanent scientific and technical maintenance (financing problem) and institutional cooperation and agreements (weather and forecast data, feedback system - validation etc.)

2. Extended and better data base (soil characteristics, crop risks, damage, yields etc.) for further calibration and validation are needed to improve performance and identify / reduce regional biases and uncertainties.

3. Organizing permanent stakeholder/user feedbacks to increase user acceptance and fitting to user needs

ADA webpage: ada.boku.ac.at

Thank you for your attention!