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European Commission
Horizon 2020
European Union Funding for Research & Innovation

Austrian system for drought monitoring

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Workshop 2018

The aim of the ADA project (2013-2016) was 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

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ADA soil water balance settings

- Soil depth considered for the soil water balance computations:

    - grass: top layer 0-20 cm, sub layer 20-40 cm
    - arable crops: top layer 0-40 cm, sub layer 40-100 cm

- Weighting factor for the two soil layers: 60% (top), 40% (sub). I.e. The top layer is responsible for 60% of the total evapotranspiration value and the sub layer for 40%.

- Full water saturation at the beginning of each computation year (optional: continuous water saturation computation without reset)

- Computation of all water balance parameters related to calculated crop specific phenological stages (Kc-factors)

ADA GIS model structure

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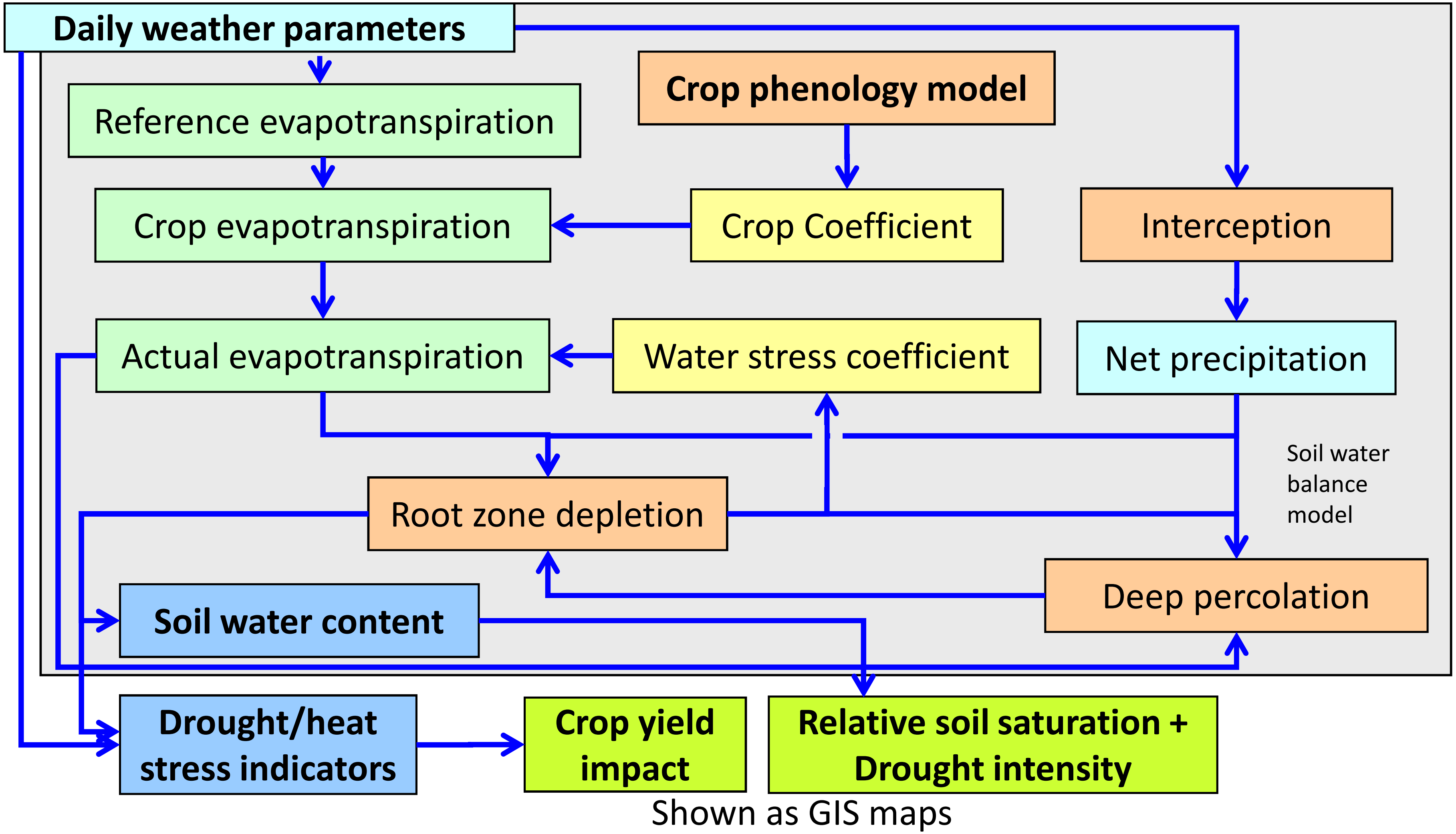
Soil water balance model SOILCLIM (colored area) based on ALLEN et al. (1998):
Crop evapotranspiration, FAO paper No 56



Soil water content [mm] - swc: result of the water balance computations

- The maximum soil water content equals the soil water content at field capacity **swc_fc**. With no rain, day for day the swc is reduced due to the water use of the plants till it reaches the water content at permanent wilting point **wilt**. From that point on no more water can be extracted by the plants and the water content at permanent wilting point is kept in the soil for extended periods.

- swc, swc_fc and wilt enable the computation of the relative soil saturation

Relative soil saturation [%] - rss (=MAPPED OUTPUT)

The soil water content is expressed as proportion of water soil profile saturation in %, denominated as relative soil saturation rss

- rss = (swc - wilt) / (swc_fc - wilt)*

*Trnka M.; Hlavinka P.; Semerádová D.; Balek J.; Možný M.; Štěpánek P.; Zahradníček P.; Hayes M.; Eitzinger J. and Žalud Z. (2014): Drought monitor for the Czech Republic - www.intersucho.cz. Rožnovský, J., Litschmann, T., (eds): Mendel a bioklimatologie. Brno, 3.– 5.9.2014, ISBN978-80-210-69831

Drought intensity (= MAPPED OUTPUT)

- ADA uses the soil water content as crop specific drought indicator to quantify the so called drought intensity.
- Drought intensity can be expressed as a measure of deviation from the statistically derived „normal“ state. For each grid cell the current soil water content at a given day is compared to the soil water content distribution of the historical years from 1981 till 2015 for the same day +/- 10 days. The drought intensity value expresses the probability of repetition of soil moisture in the given day.
- ADA soil water content deviations are statistically calculated using the percentile method.

Heat and drought stress indicators and sums

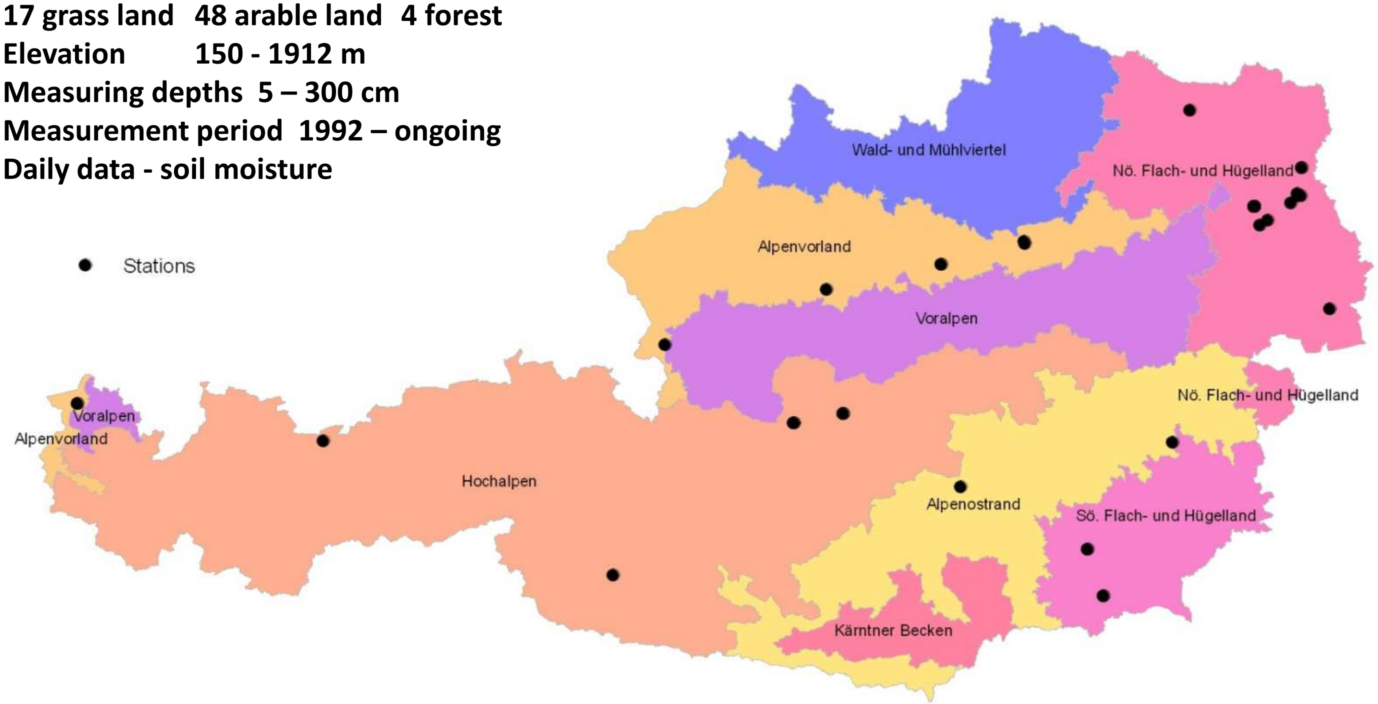
- Heat and drought stress indicators are calculated each day of the year within the water balance computation module of the ADA software.
- Drought and stress indicator <u>sums</u> are calculated from crop specific start days till the end of the crop‘s phenological „late“ phase (grass: till the second cut of a 3 cut regime).

Crop yield reduction (=MAPPED OUTPUT)

- Yield reduction formulas have been developed by the project partners and have been incorporated into the ADA software.
- The yield reduction formulas are linear functions with crop specific equation coefficients A and B as well as the drought stress indicator sum as the independent variable x: $y = B*x + A$
- Computation Results: relative yield reduction as percentage of maximum yield
- Yield reduction classification: 0-5% 5-30% 30-60% >60%

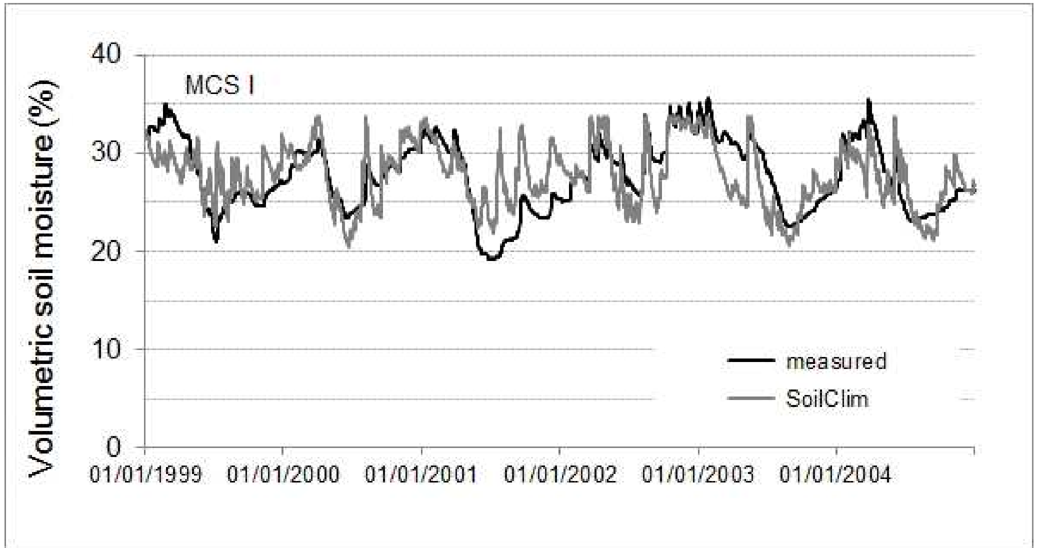
Validation data base for simulated soil moisture – Available Soil Water Stations & Main Production Areas

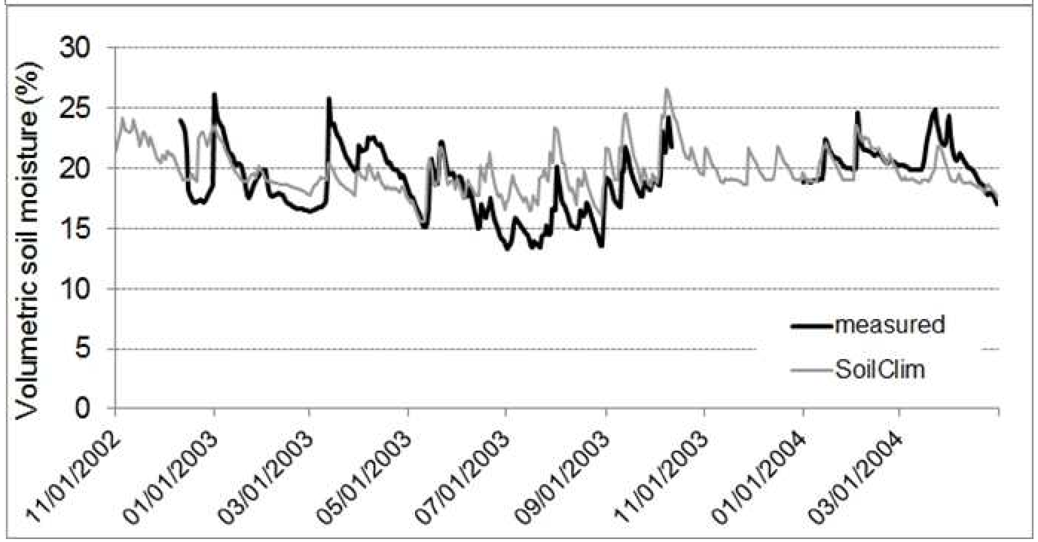
21 Locations 69 plots
17 grass land 48 arable land 4 forest
Elevation 150 - 1912 m
Measuring depths 5 – 300 cm
Measurement period 1992 – ongoing
Daily data - soil moisture



Krammer, 2013

Soil water balance model (SOILCLIM) - evaluation





Examples of the SoilClim model evaluation

at the Hirschstetten lysimeter site (above)

and grassland site Gumpemstein (below)

(top soil layer 0-40 cm).

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, ..)

Estimating drought / heat 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 (stress indicators) and yield vulnerability (yield depletion from unstressed conditions)

Methods: Statistical analysis of crop yield data

Crop Coefficient Model for ADA

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**

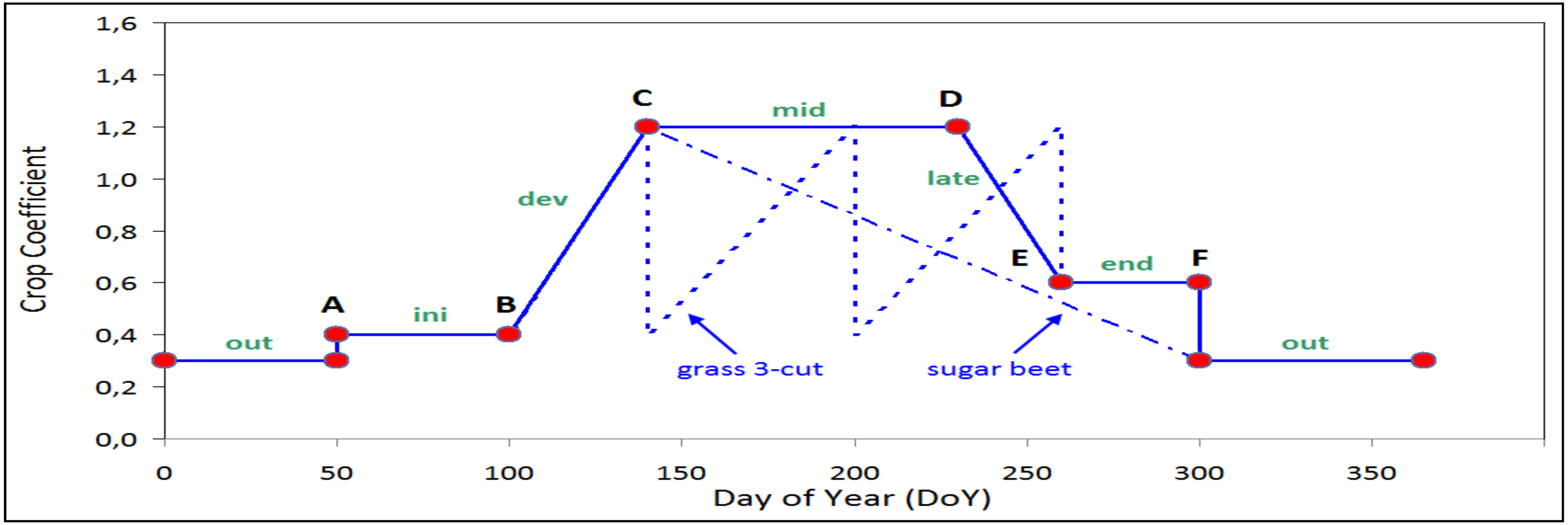
Base temperature for calculation of degree day temperature sum (BT): **5 °C**

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

Culture	Initial (Evaporation)		Crop Development		Mid-Season		Late Season		End of Growing			
	Entry of A		Entry of B		Entry of C		Entry of D		Entry of E		Entry of F	
	Kc	Time	Kc	Time	Kc	Time	Kc	Time	Kc	Time	Kc	Time
Grassland (3-cut)	Will be done by LFZ Raumberg-Gumpenstein (according to Schaumberger, 2011)											
Winter Wheat	0.4	01.03.	0.4	SGS	1.2	350	1.2	692	0.5	+14 days	0.5	30.11.
Spring Barley	0.4	01.03.	0.4	SGS	1.2	502	1.2	568	0.5	+14 days	0.5	30.11.
Spring Maize	0.4	01.04.	0.4	SGS-M	1.2	249	1.2	1238	0.5	+14 days	0.5	30.11.
Sugar Beet	0.4	01.03.	0.4	300	1.2	2400					1.1	31.12.

Phenology model

(to be used for evapotranspiration calculation and stress indicators)



Stress indicators

Impact of drought and heat on crop stress (by risk measures) and yield level (by vulnerability measures)

A. Crop risk measures

1. **a) General drought indicator** (soil water content deviation in regard to the seasonal normal) **and b) crop specific water stress factor** (plant available soil water (AWC) content depletion - linear increasing stress beyond 30% AWC depletion)

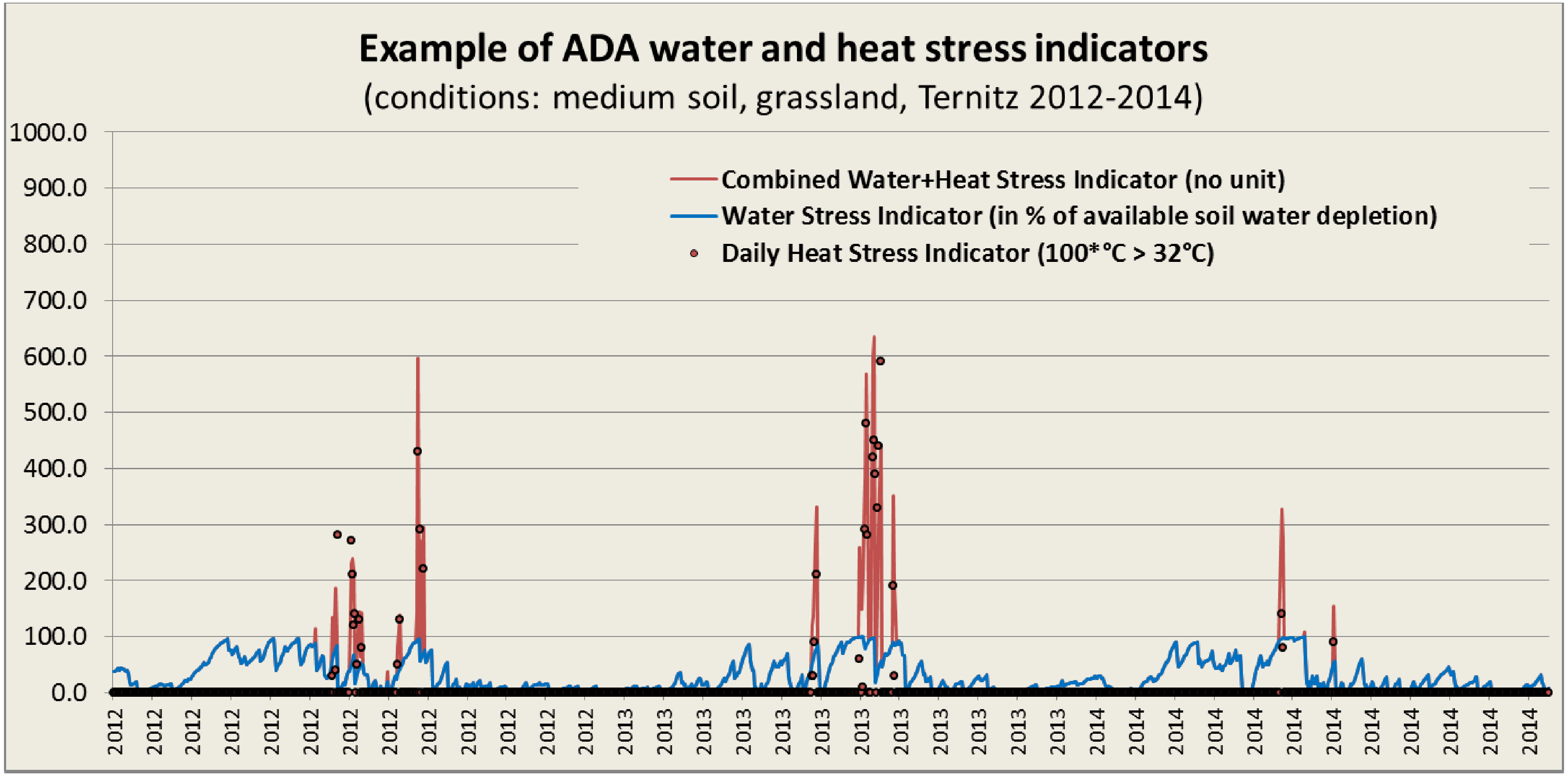
2. Heat stress factor (actual and accumulated)
- number of days above maximum temperature limit
-Duration above a critical Temperature

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)

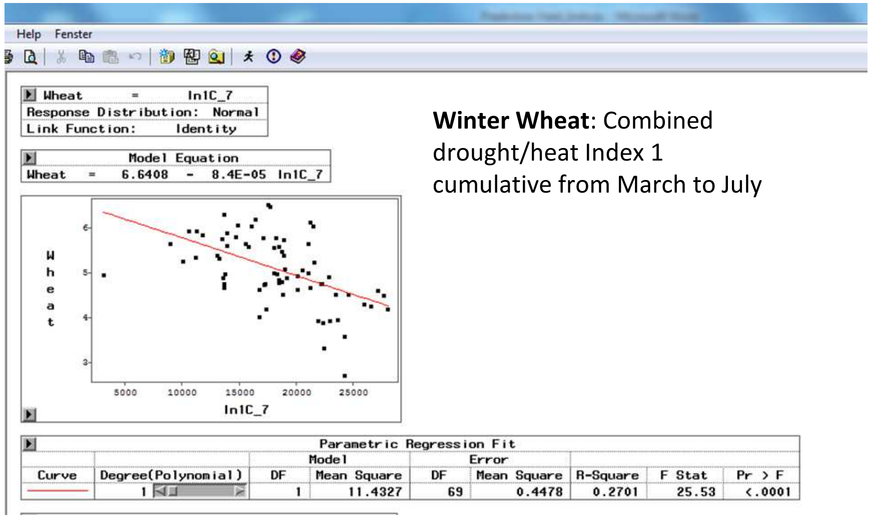
B. Crop vulnerability measures

1. **Crop specific heat and drought stress response at different phenological states expressed by yield depletion from normal**

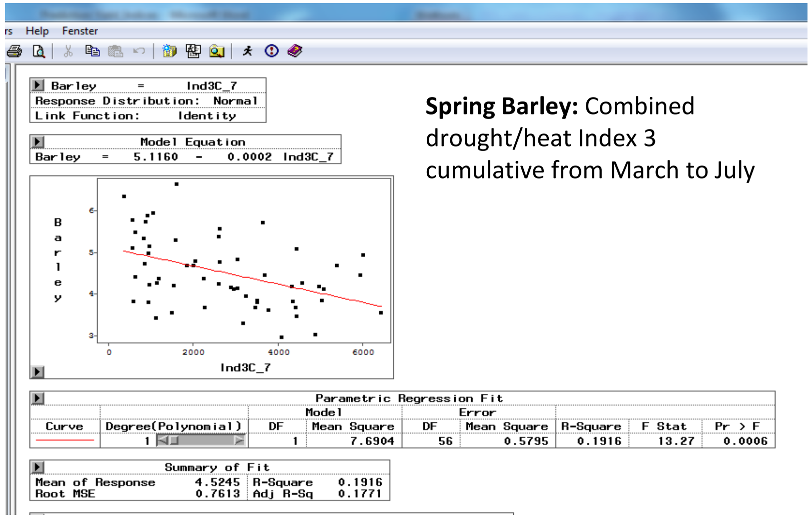
Calibration/validation with observed crop yield data in Lower Austria, Burgenland, Styria (district level)


Example of ADA water and heat stress indicators
(conditions: medium soil, grassland, Ternitz 2012-2014)
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Combined Water+Heat Stress Indicator (no unit)
Water Stress Indicator (in % of available soil water depletion)
Daily Heat Stress Indicator (100*°C > 32°C)
2012
2013
2014

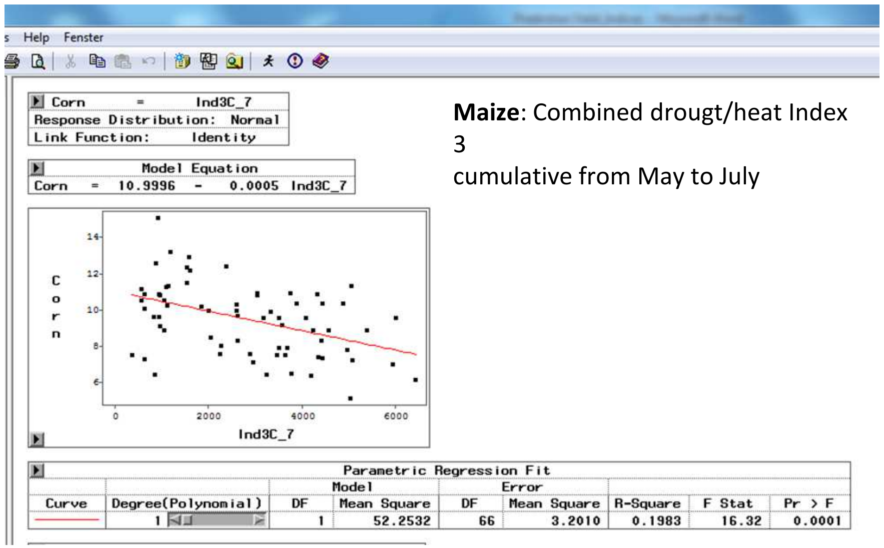
Performance of pre-defined combined drought-heat impact indicators



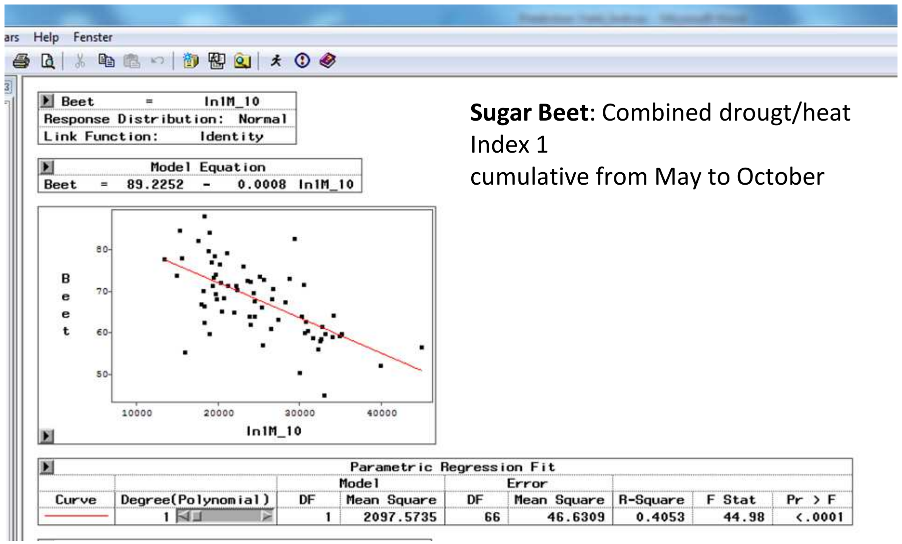
Winter Wheat: Combined drought/heat Index 1 cumulative from March to July



Spring Barley: Combined drought/heat Index 3 cumulative from March to July



Maize: Combined drougt/heat Index 3 cumulative from May to July



Sugar Beet: Combined drougt/heat Index 1 cumulative from May to October

Best performing stress and yield impact indicators

Crop	Daily heat indicator	Daily drought indicator	Daily drought/Heat indicator		Actually implemented yield depression functions		
Grassland 2nd cut		WSI = DR * 100.0 / TAW			YD = 87.53 + (-.0055 * Σ WSI)	Σ 1.5. - cut date	R^2=0.23
Winter Wheat	Σ HDH > 27	WSI = DR * 100.0 / TAW	TM > 26: CSI = WSI * (TM -25.0) TM < 26: CSI=WSI		YD = 6.64 + (-.000084 * Σ CSI)	Σ 1.3. – harvest	R^2=0.27
Spring barley	Σ HDH > 27	WSI = DR * 100.0 / TAW	WSI > 33 & TM>30: CSI= ((TM-29)*WSI)-33		YD = 5.11 + (-.0002 * Σ CSI)	Σ 1.3. – harvest	R^2=0.20
Maize		WSI = DR * 100.0 / TAW	WSI > 33 & TM>30: CSI= ((TM-29)*WSI)-33		YD = 10.99 + (-.0005 * Σ CSI)	Σ 1.5. - harvest	R^2=0.20
Sugar beet		WSI = DR * 100.0 / TAW	TM > 26: CSI = WSI * (TM - 25.0) TM < 26: CSI=WSI		YD = 89.22 + (-.0008 * Σ CSI)	Σ 1.5. - harvest	R^2=0.41

WSI = water stress indicator [%]
DR = root zone depletion [mm]
TAW = available soil water content at available field capacity [mm]
CSI = combined water and heat stress indicator [-]
TM = maximum daily temperature [°C]
YD = Yield depression relative to not stressed conditions [%]
HDH: Heat Degree Hours [°C]

ADA forecast data & facts

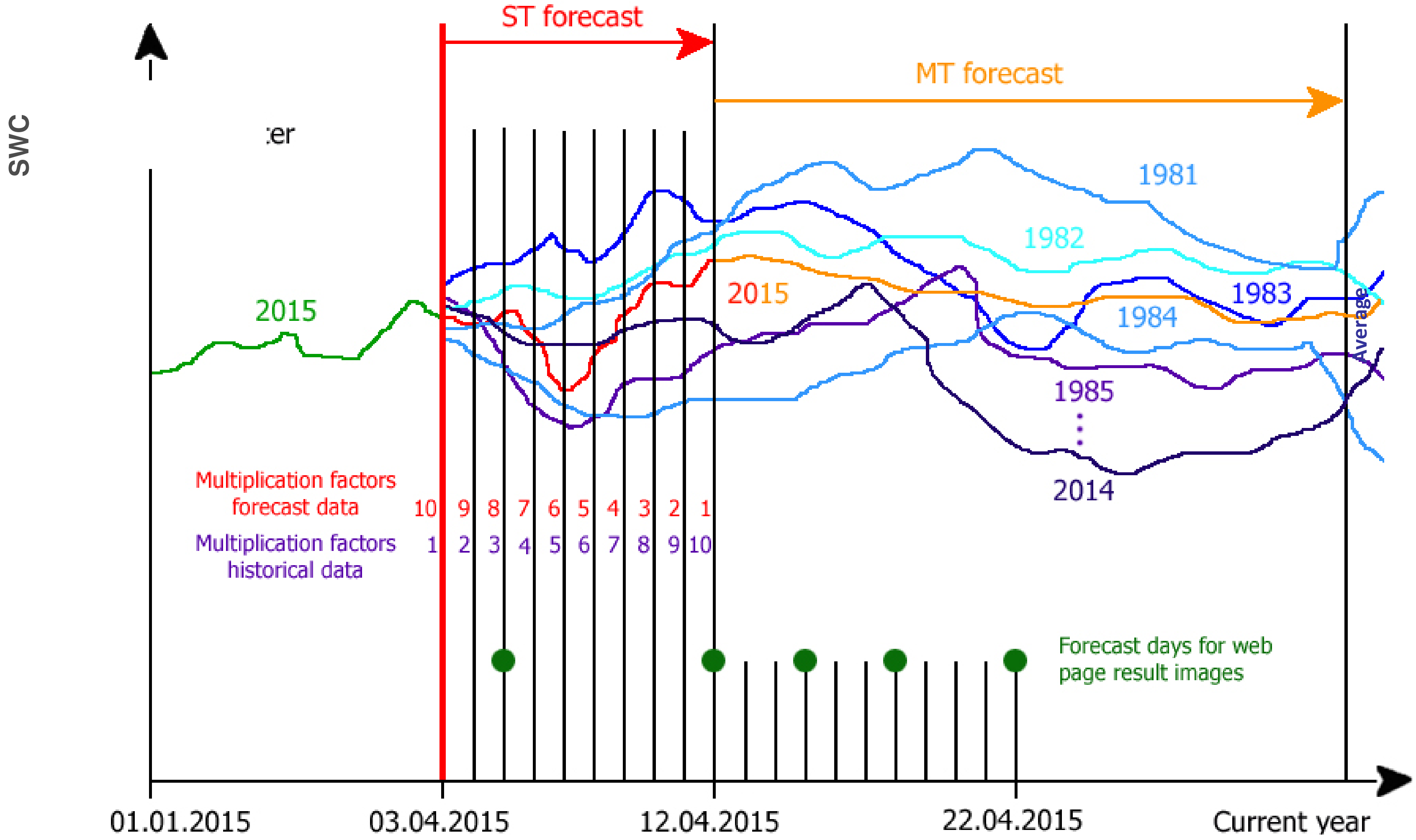
- ADA forecast computations are based on meteorological forecast data (short term forecast of 10 days) and averaged meteorological data of historical years (medium/long term forecast of any number of days).

- Meteorological forecast data is delivered by ZAMG (Zentralanstalt für Meteorologie und Geodynamik, Wien). Historical meteorological data is available from the ADA database.

- The ADA computation time (presently up to 2 days for whole Austria) allows forecast updates every three days.

- All ADA forecast drought computations (phenological entry dates, RSS, DI, yield reduction, etc.) are run in analogy to the computations of historical years – the only difference is the manipulated meteorological input data.

Forecast using weighted and averaged meteorological data



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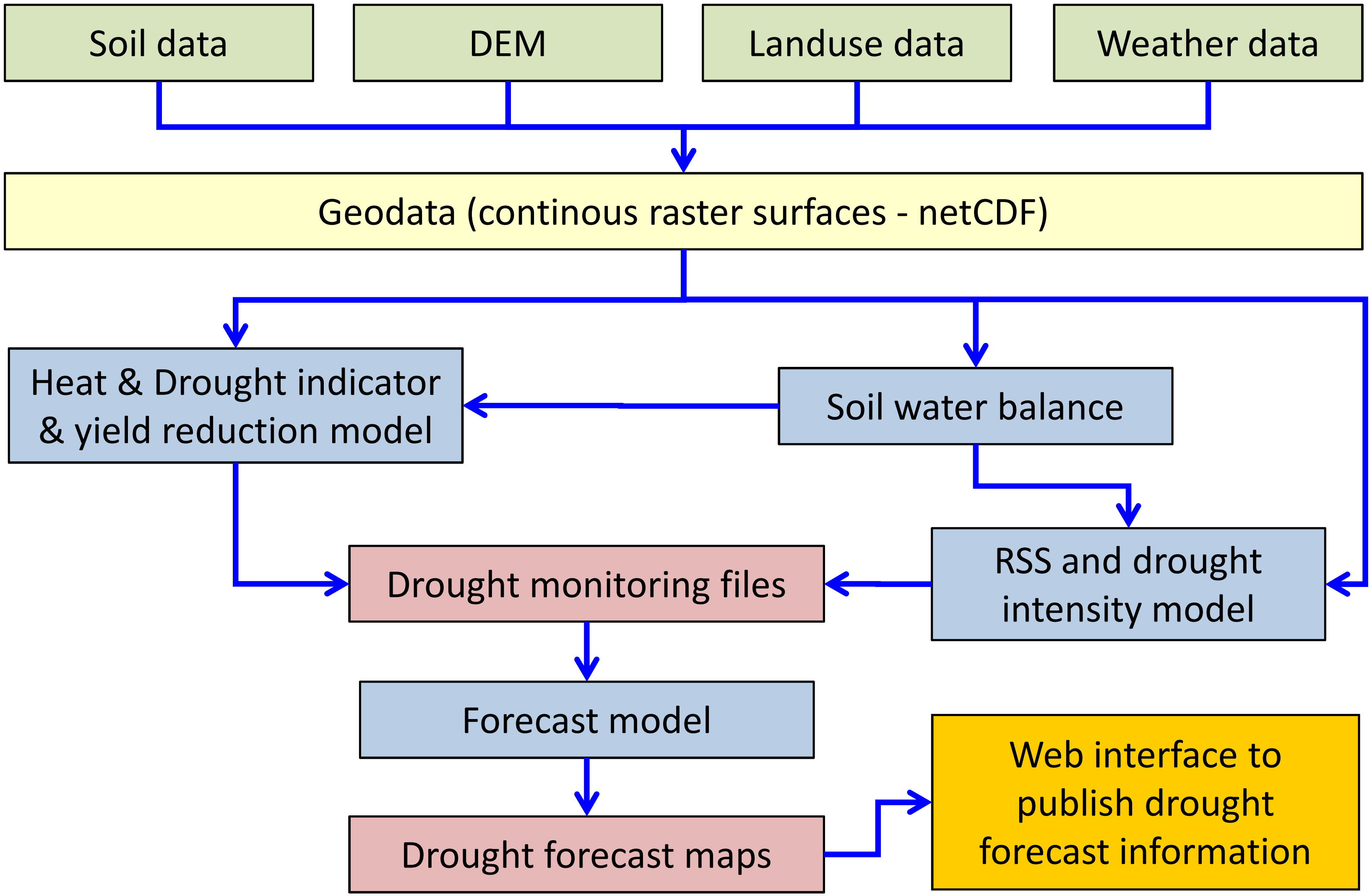
ADA: Data flow in the GIS model



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INCA Data Input Specifications

Parameter	ab Jahr	Forecast (d)	Auflösung	Anmerkung
Minimumtemperatur (24 h) [°C d^{-1}]	2003	3 bzw. 10	1 km*)	
Maximumtemperatur (24 h) [°C d^{-1}]	2003	3 bzw. 10	1 km	
Mitteltemperatur (24 h) [°C d^{-1}]	2003	3 bzw. 10	1 km	
Tagesmitteltemperatur (12 h) [°C d^{-1}]	2003	3 bzw. 10	1 km	abhängig von Modellen
Globalstrahlung [MJ m^{-2} d^{-1}]	2003	3 bzw. 10	1 km	Umrechnung auf MJ m^{-2}
Relative Luftfeuchte [% d^{-1}]	2003	3 bzw. 10	1 km	oder Evapotranspiration
Wind [m s^{-1} d^{-1}]	2003	3 bzw. 10	1 km	oder Evapotranspiration
Evapotranspiration (PM) [mm d^{-1}]	2003	3 bzw. 10	1 km	
Schneebedeckung (SWE) [mm d^{-1}]	2003	3 bzw. 10	1 km	vorerst nur Ja/Nein (mit W. Schöner besprechen)
Niederschlag [mm d^{-1}]	2003	3 bzw. 10	1 km	

*) Die räumliche Auflösung der Wettermodelle liegt ursprünglich bei 4.8km für die nächsten 3 Tage (ALARO) und ca. 16.km für die nächsten 10 Tage (ECMWF). Die Daten werden jedoch auf das 1km INCA Gitter interpoliert und in dieser Auflösung zur Verfügung gestellt.

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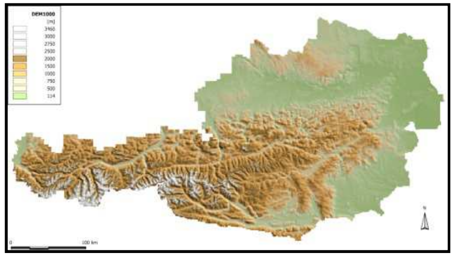
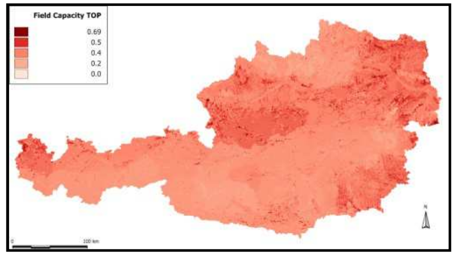
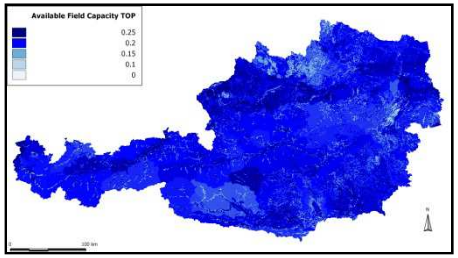
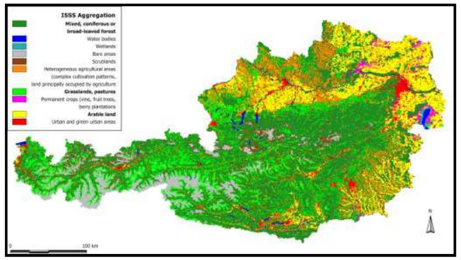
Which data is used?

- Digital elevation model [m]: 1 layer
- Field capacity [Vol%]: 1 top layer (0,4 m)
  1 sub layer (0,6 m)
- Available field cap. [Vol%]: 1 top layer (0,4 m)
  1 sub layer (0,6 m)
- Agricultural landuse types: Grassland and arable land: winter wheat, spring barley, spring maize, sugar beet
- Met. data: Relative humidity [%], Wind [m/s],
  Temperature [°C], Precipitation [mm],
  Radiation [MJ/m² day] *





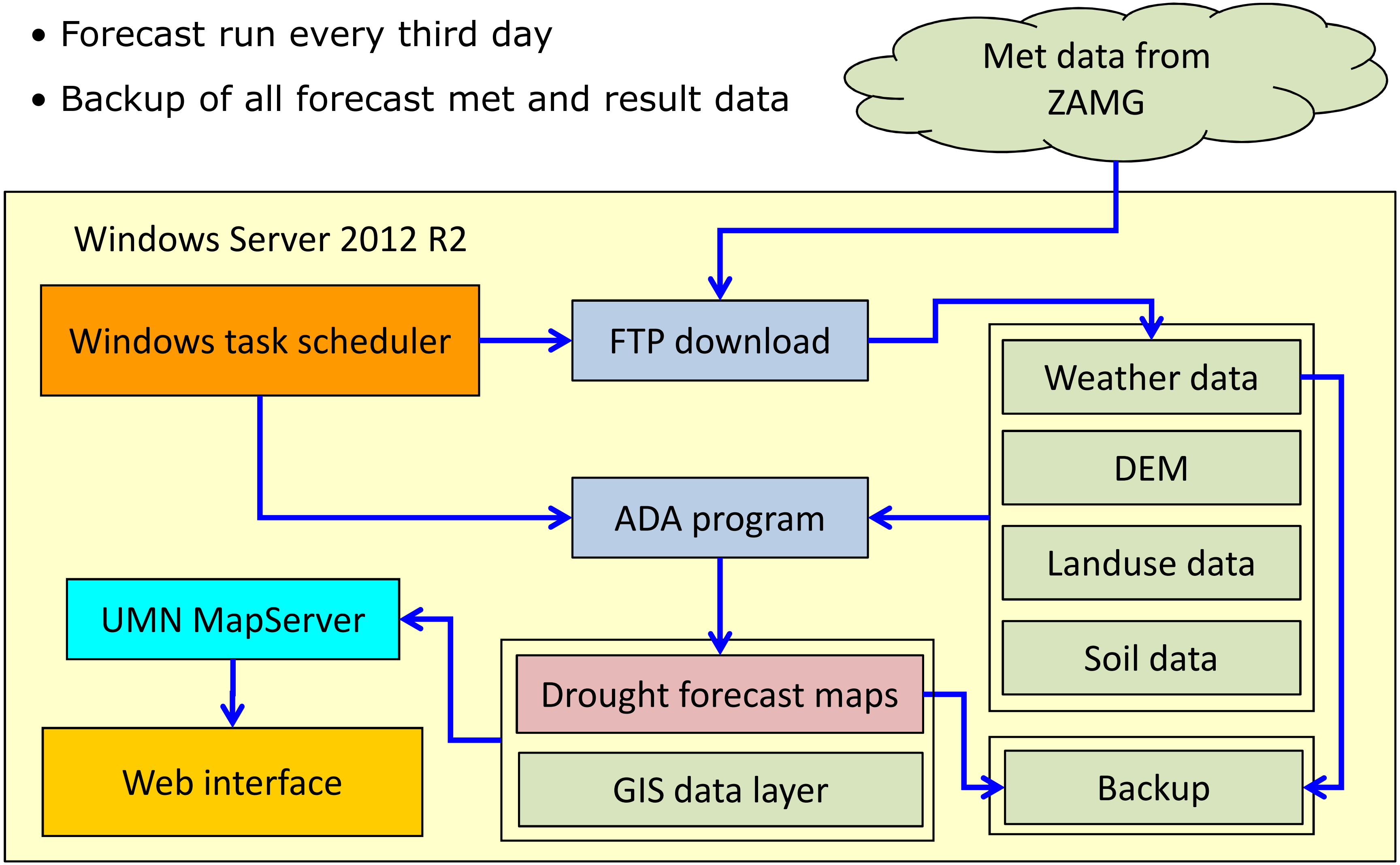




* **1981 - 2002:** Spatial interpolation of weather data for the period before INCA data is available
2003 – now (+ 10 days forecast): INCA weather data interpolated by ZAMG

ADA web architecture

- Forecast run every third day
- Backup of all forecast met and result data

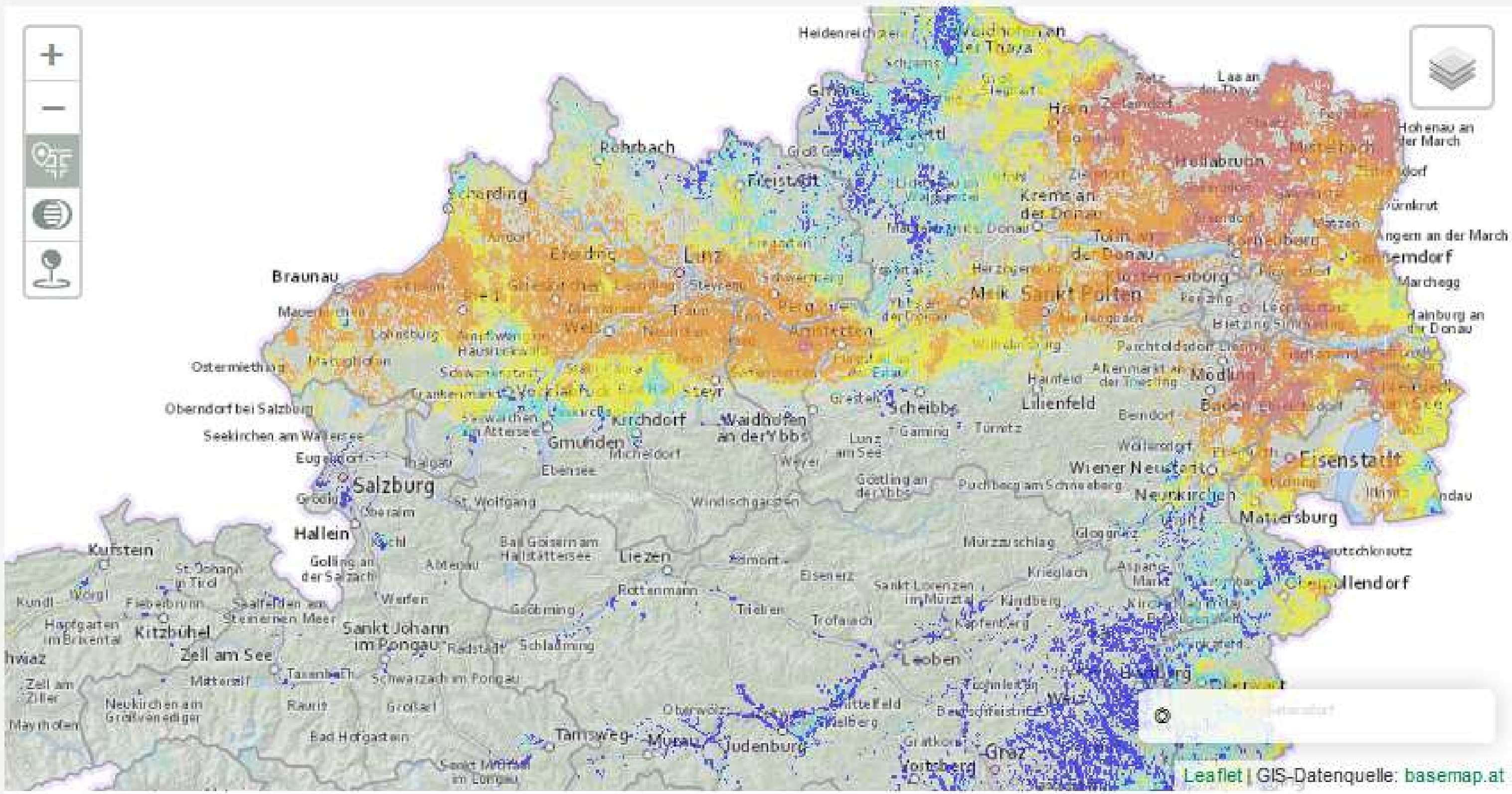


Dieser Wert gibt nutzpflanzenspezifisch die noch für Pflanzen verfügbare Wassermenge relativ zur gesamten Speicherkapazität des Bodens an. Die Werte basieren auf Bodenwasserbilanzrechnungen mit einer Bodenreferenztiefe von 0-40 cm für Grünland und 0-100 cm für die vier Ackerfrüchte.
Außerhalb der jeweiligen Wachstumsperiode erfolgt die Berechnung bei den Ackerfrüchten für nicht bewachsenen Boden (Brache)

Pflanzenverfügbares Bodenwasser | Trockenheitsintensität | Stressbelastung

Winterwheat

- 10%-20%
- 20%-30%
- 30%-50%
- 50%-70%
- 70%-100%



Karte für gesamtes Jahr laden

25.6.18

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Macher

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Trocke und Vo ARIS

Eine Kurzvors Forschungsp Einführung in Berechnung

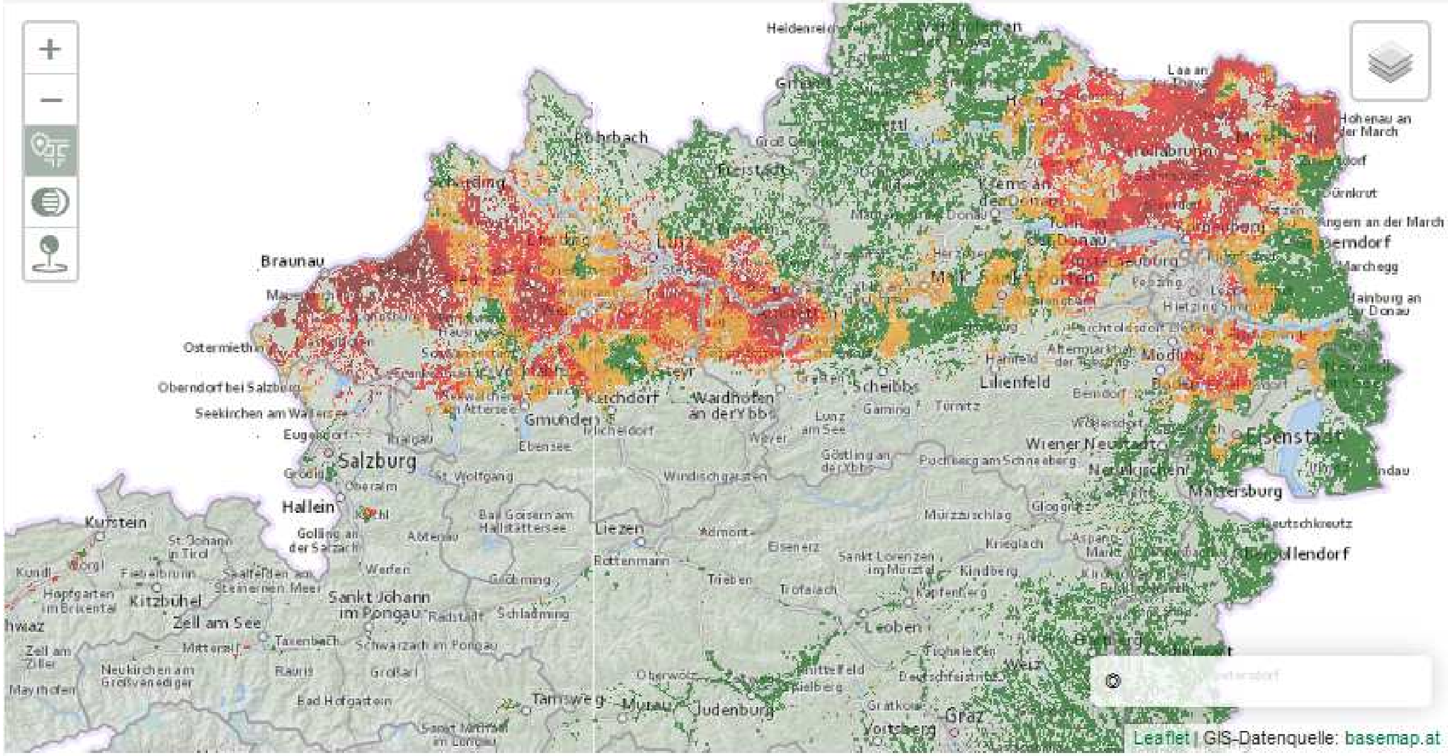
Bedien

Dieser Wert gibt die aktuelle Abweichung des **pflanzenverfügbaren** Wassers im Vergleich zum langjährigen Mittel (1981 bis heute) an. So bedeutet ein hoher Trockenheitsintensitätswert an einem beliebigen Tag des Berechnungsjahres, dass der Bodenwassergehalt an diesem Tag signifikant geringer ist, als im langjährigen Mittel dieses Tages. Die Trockenheitsintensitätswerte basieren auf Bodenwasserbilanzberechnungen mit einer Bodenreferenztiefe von 0-40 cm für Grünland und 0-100 cm für die vier Ackerfrüchte.

- außergewöhnlich t
- signifikant trocken
- moderat trockener
- mäßig trockener
- etwas trockener
- im langjährigen Mi feuchter

Pflanzenverfügbares Bodenwasser | Trockenheitsintensität | Stressbelastung

Winterwheat



Karte für gesamtes Jahr laden

25.6.18

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Machen Sie

Wir bitten um Ihr F aktuellen Trockenh an Ihrem Standort: questionnaire.inter

Trockenheit und Vorhers ARIS

Eine Kurzvorstellun Forschungsprojekt Einführung in Date Berechnung

Bedienungsl

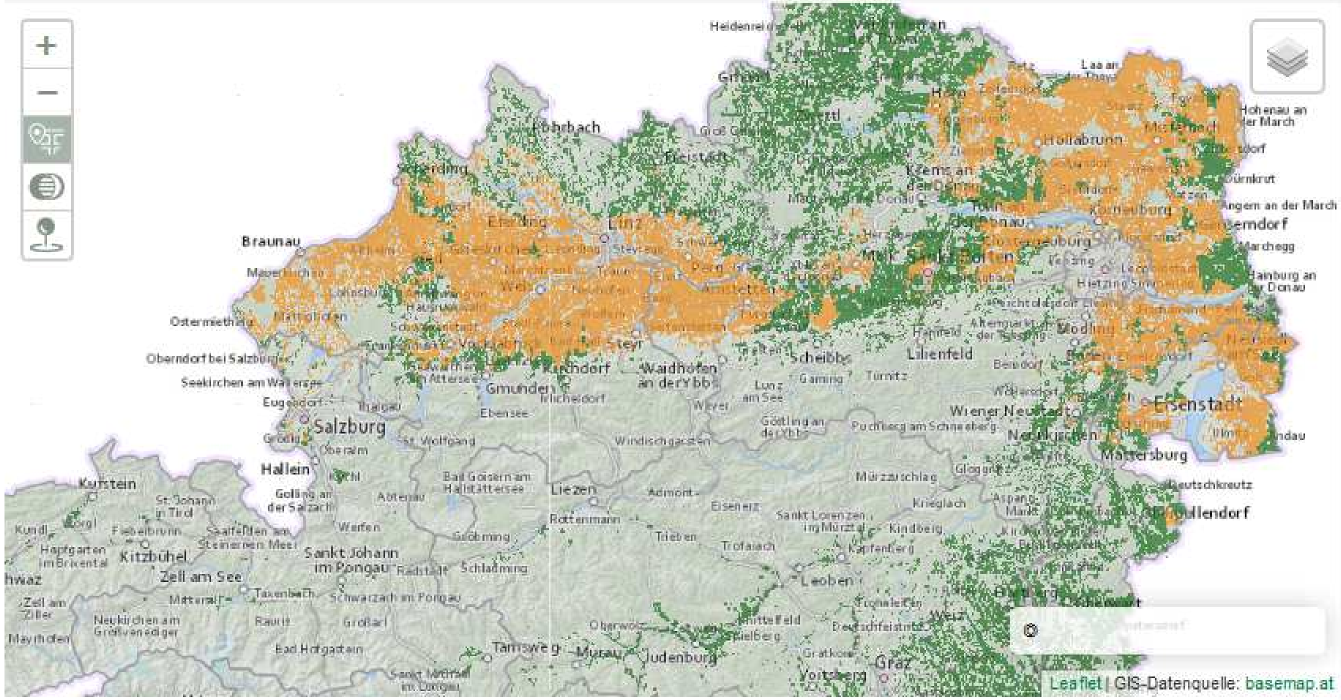
- hoch bis sehr hoch
- moderat bis ausge
- gering bis nicht vo

Dieser Indikator stellt den in der Wachstumsperiode der jeweiligen Nutzpflanze bisher aufgelaufenen Trocken- und Hitzestress kumulativ dar. Dabei geht für Grünland nur der Trockenstress, für die 4 Feldfrüchte der Trocken- und Hitzestress kombiniert ein, je nach Nutzpflanze mit unterschiedlichen Stressempfindlichkeiten.

Da kumulativ, kann dieser Wert bis zum Ende der pflanzenspezifischen Wachstumsperiode nur zunehmen und wird danach als konstanter Wert angezeigt. Ertragsauswirkungen können nur bedingt, unter Nutzung eigener standortspezifischer Beobachtungen abgeschätzt werden.

Pflanzenverfügbares Bodenwasser | Trockenheitsintensität | Stressbelastung

Winterwheat



Karte für gesamtes Jahr laden

25.6.18

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Machen Sie

Wir bitten um Ihr F
aktuellen Trocken
an Ihrem Standort
questionnaire.inte

Trockenheit und Vorhers ARIS

Eine Kurzvorstellu
Forschungsprojek
Einführung in Date
Berechnung

Bedienungs

So kommen Sie sc
unkompliziert zu I
Monitoring- und
Vorhersagedaten

Ansprechpa

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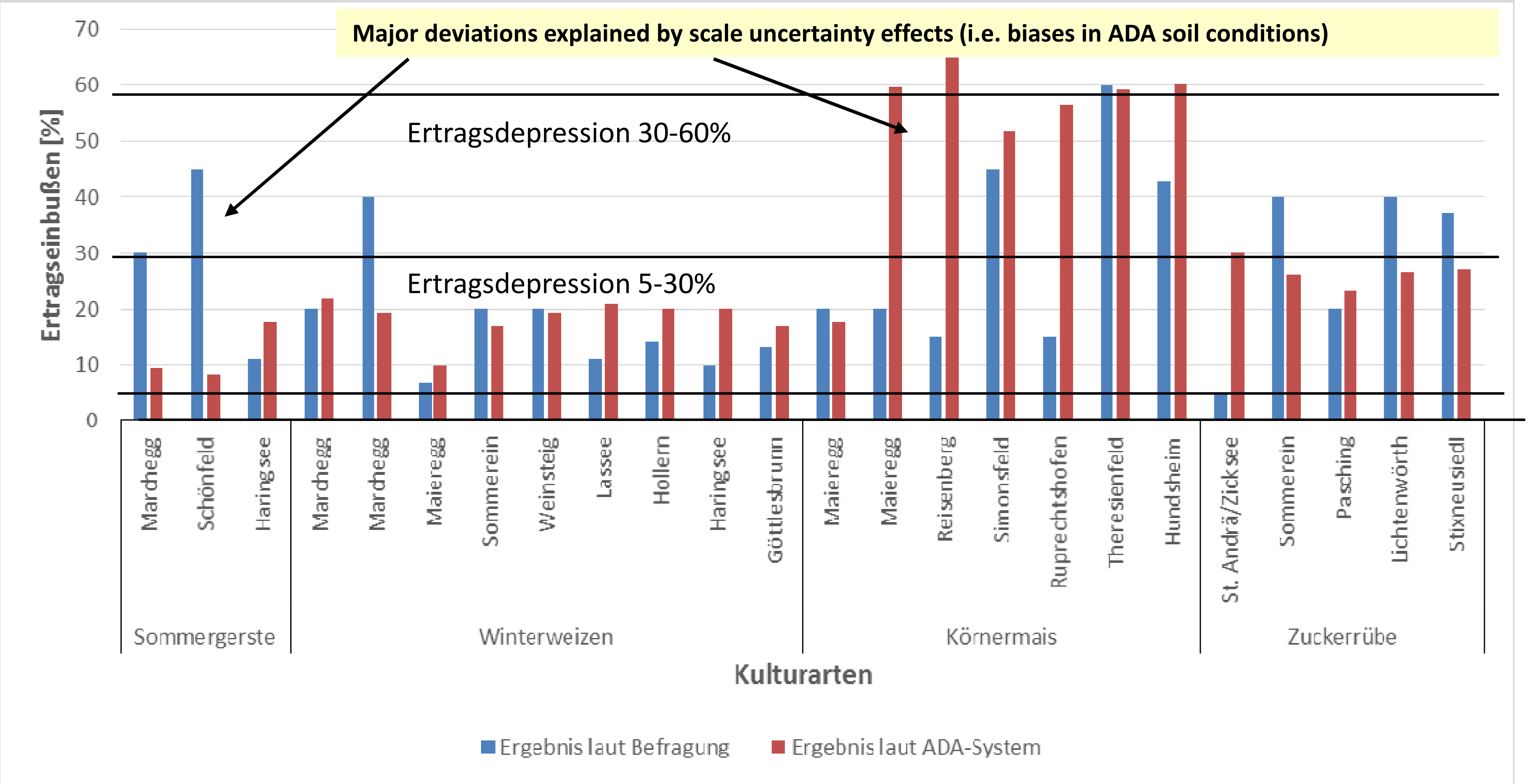
ADA test for year 2015: Independent feedbacks by farmers (field based crop yields)



Conclusions

-Simple crop-soil water balance approach satisfactory validated

-Significant relationships of drought/heat impacts on selected main crops

-Crops differ on heat and drought responses under regional conditions in Austria

-The GIS model enables near time monitoring and forecast
of all simulated crop growing conditions and risk factors
(water balance and temperature, biomass development, drought and heat stress and yield depletion)
for agricutural land in Austria
in a high spatial resolution (0.5 x 0.5km) and daily time step.

-Operational setup and test of the system demonstrated

Potentials

1. High application potential for spatial mapping/forecast of additional weather related risk indicators (i.e. other crop risks from adverse weather conditions).

2. Performance potentials by including remote sensing products.

3. Potential for an operational multiple agricultural risk monitoring and forecasting tool.

4. International cooperation for drought/heat monitoring system increases efficiency and robustness of system performance

Recommendations

1. Operational implementation requests permanent scientific and technical maintainance (financial resources) and institutional cooperation and agreements (weather and forecast data, feedback system - validation etc.)

2. Extending and improving data bases (soil characteristics, crop risks, damage, yields etc.) for further calibration and validation are recommended for permanent improvements of performance and reduction of regional biases and uncertainties.

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

ADA webpage: ada.boku.ac.at

Thank you for your attention !