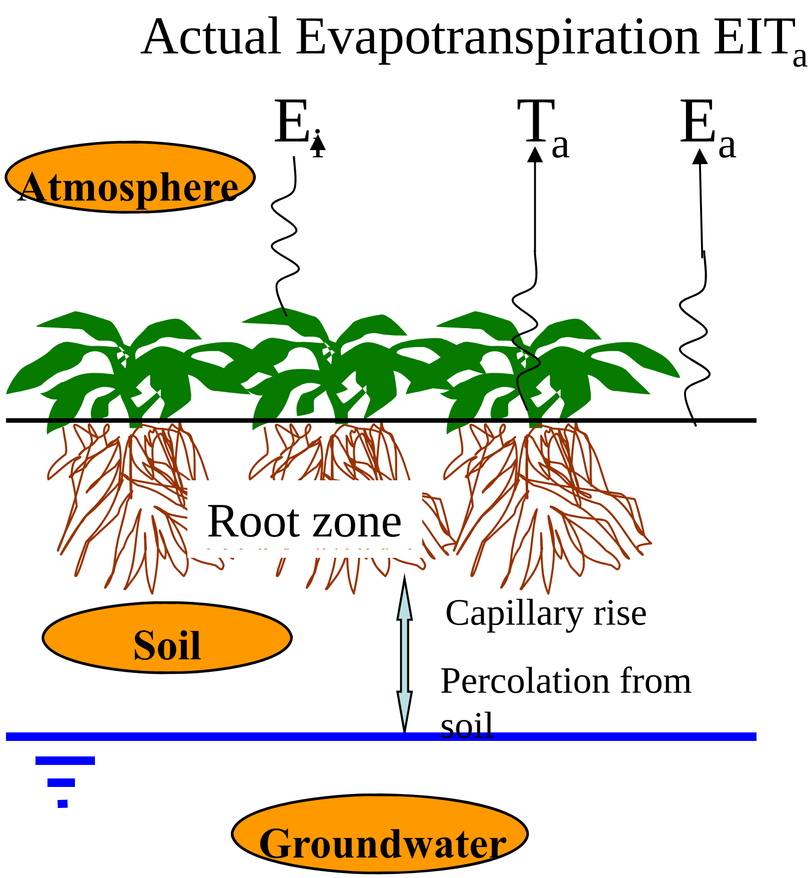
Soil water dynamics in field soils arable land, grassland, forest



- **Measurement**
- **Simulation**
- **Regionalisation**
- **Development and application of the TUB-BGR-Method**

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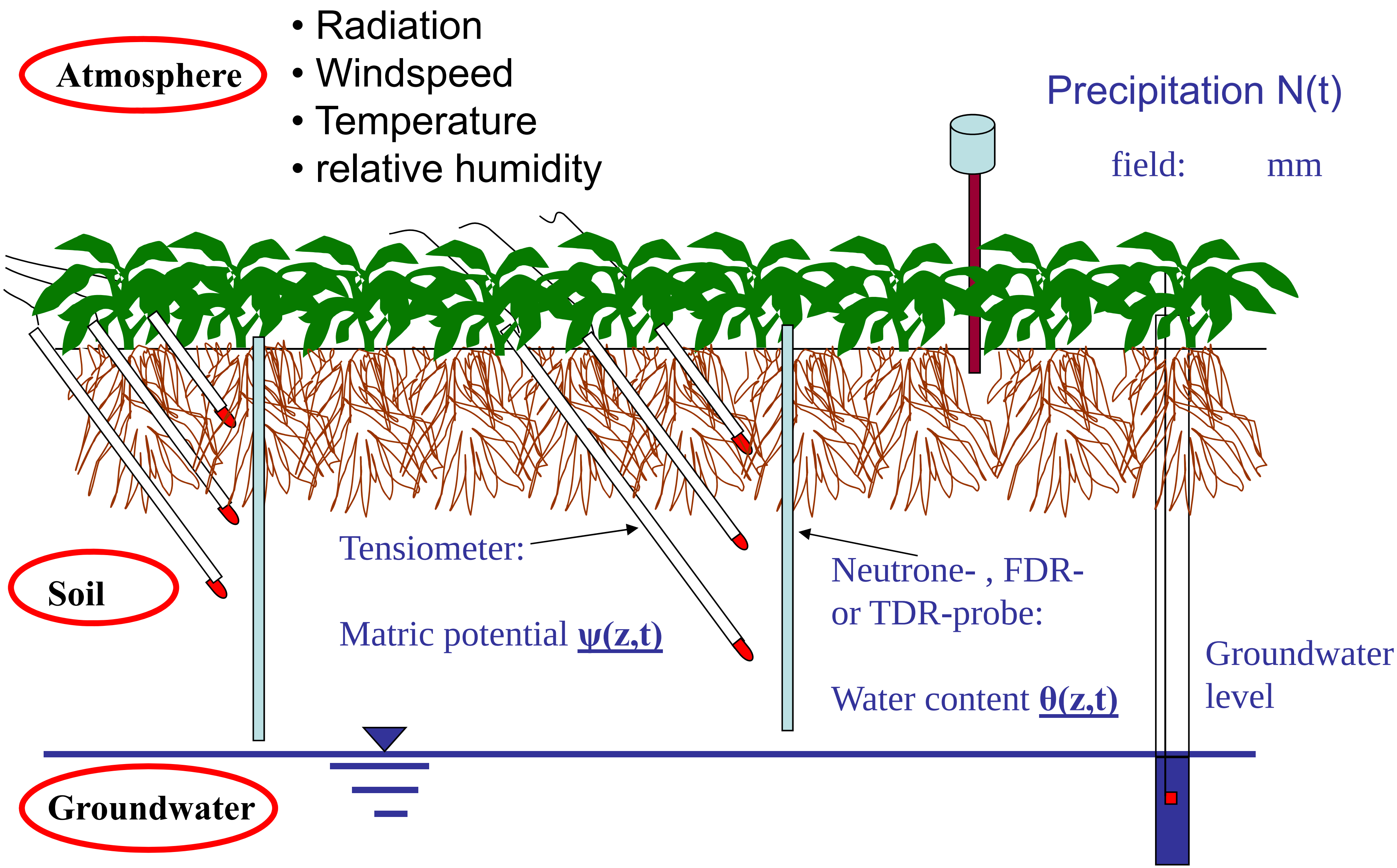
Determination of actual evapotranspiration and percolation rate



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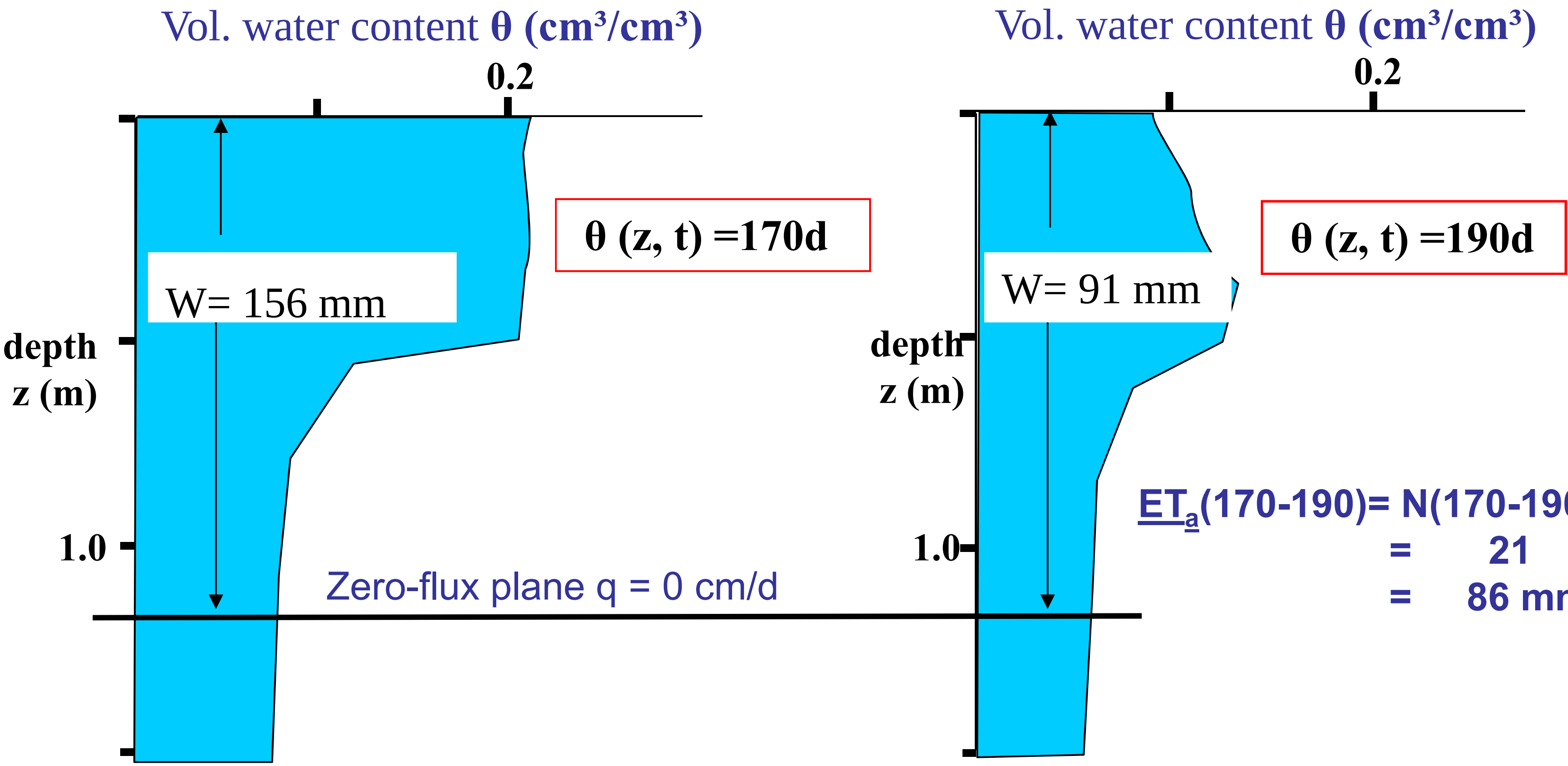
Matric potential **ψ(z,t)**
Water content **θ(z,t)**
Precipitation **N(t)**

→

Actual Evapotranspiration **$EIT_a(t)$**
Percolation rate **q(z,t)**



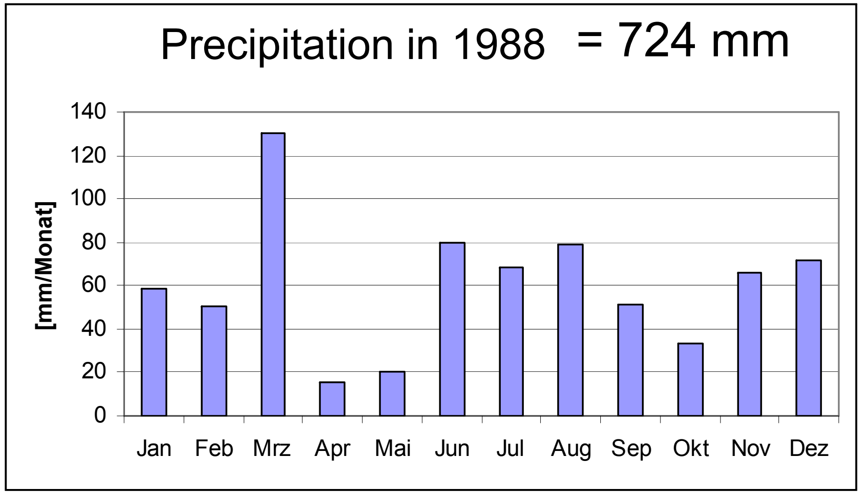
ET_a(170-190)= N(170-190) +Δ W=
= 21 + 65
= 86 mm

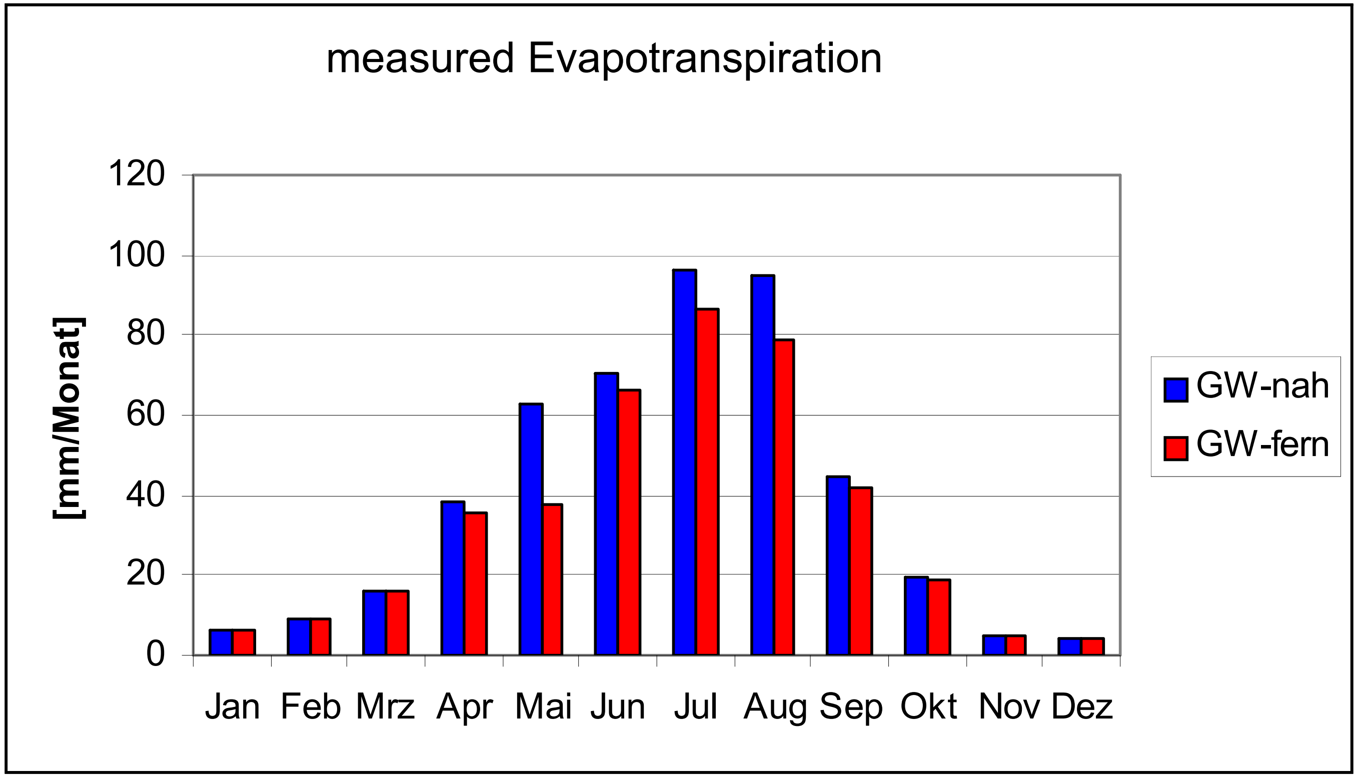
duij

Fuhrberger Feld, Arable land:

- Gley-Podsol (shallow GW-table) bzw. Podsol (deep GW-table)
  fine sandy medium sand (mSfs)
- sugar beets 1988
- groundwater levels: > 2.5 m, bzw. 1.-1.5 m

  - deep groundwater table = > 2,5 m (= GW-nah)
  - shallow groundwater table = 1- 1.5 m (= GW-fern)





GW-nah = 468 mm/a
GW-deep = 407 mm/a

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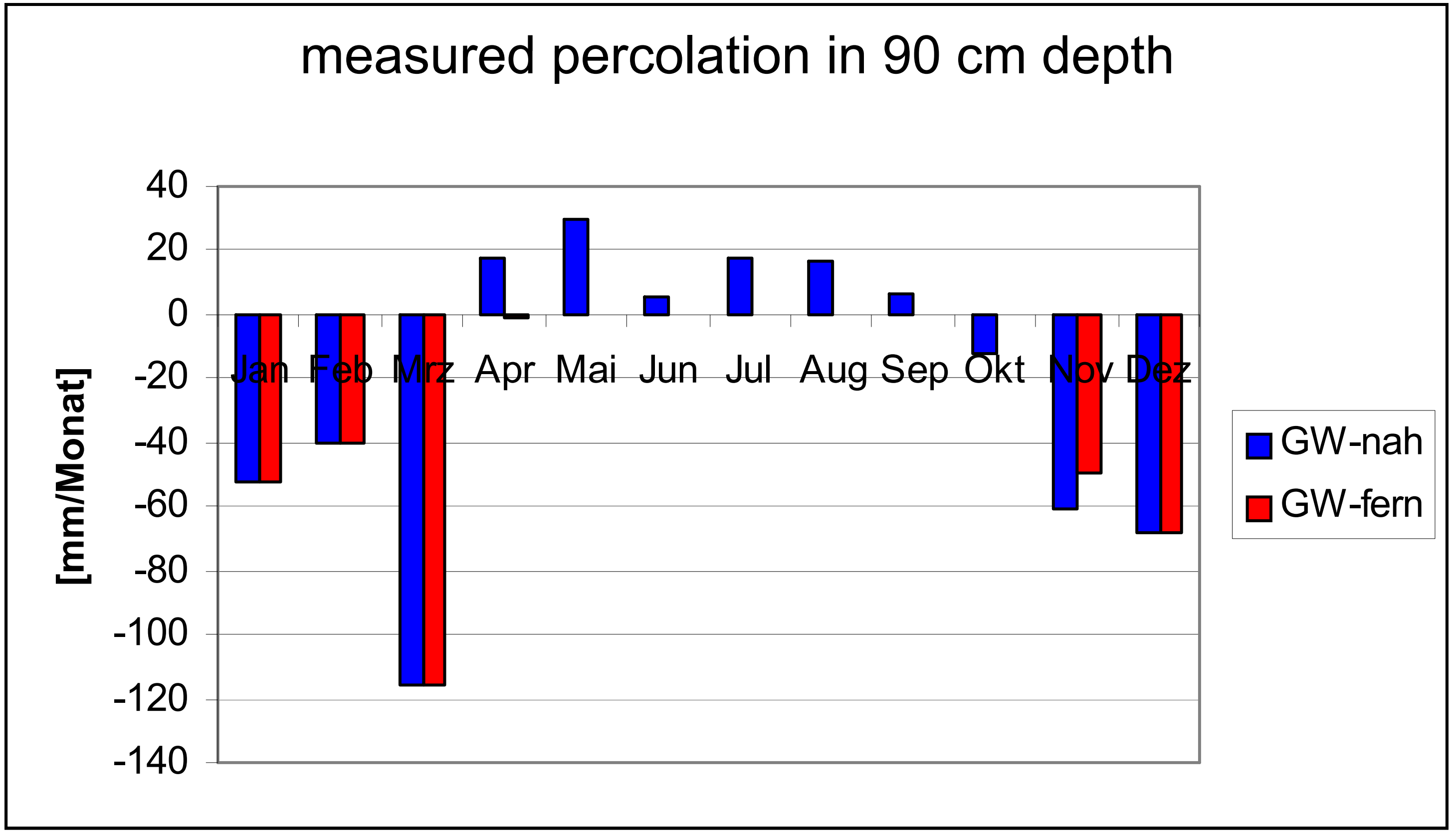
Fuhrberger Feld, Arable land:

- Gley-Podsol (shallow GW-table) resp. Podsol (deep GW-table) in fine sandy medium sands (mSfs)
- sugar beets 1988
- groundwater levels: > 2.5 m, bzw. 1.-1.5 m



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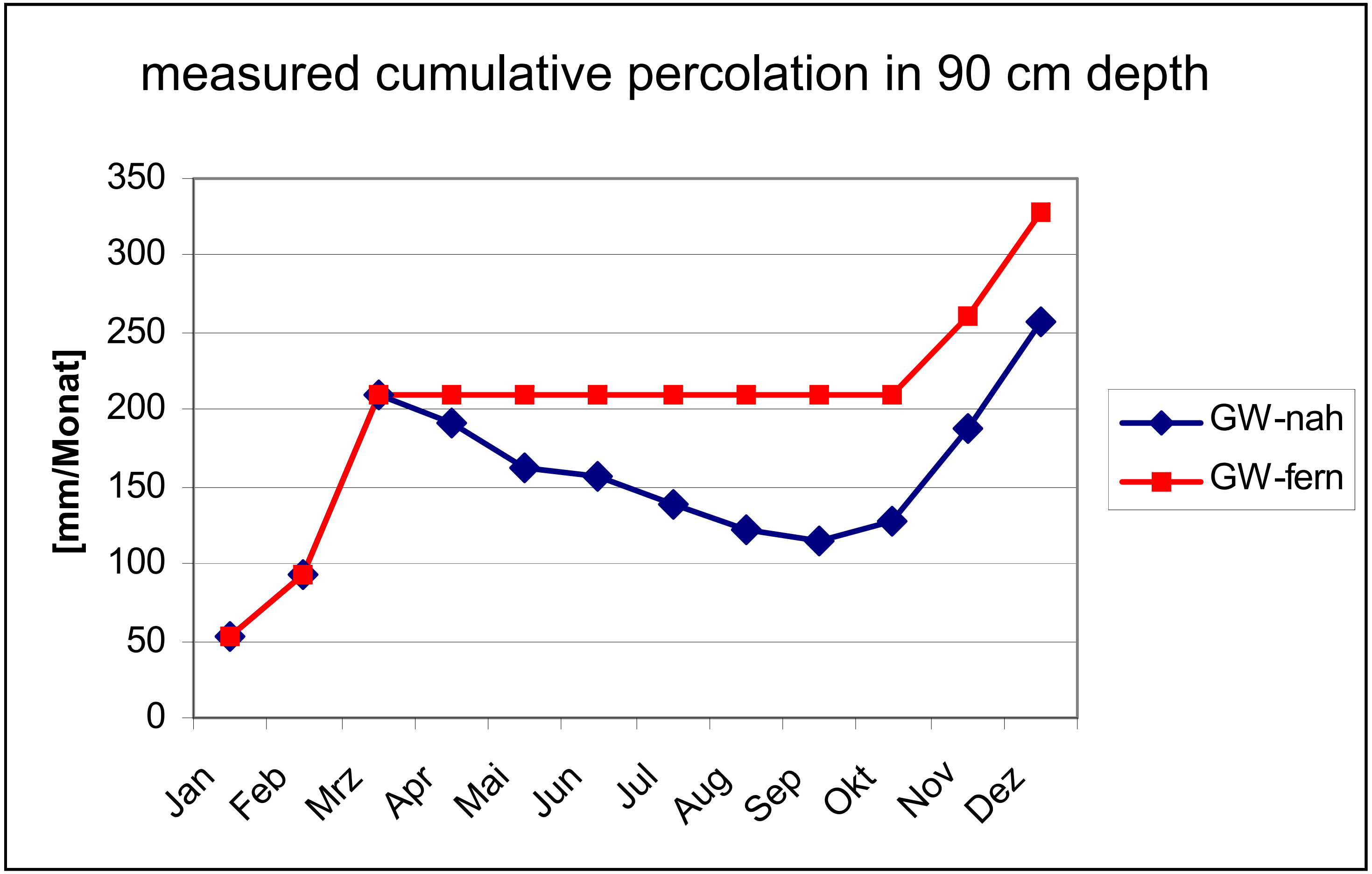
Fuhrberger Feld, Arable land:

- Gley-Podsol (shallow GW-table) resp. Podsol (deep GW-table) in fine sandy medium sands (mSfs)
- sugar beets 1988
- groundwater levels: > 2.5 m, bzw. 1.-1.5 m



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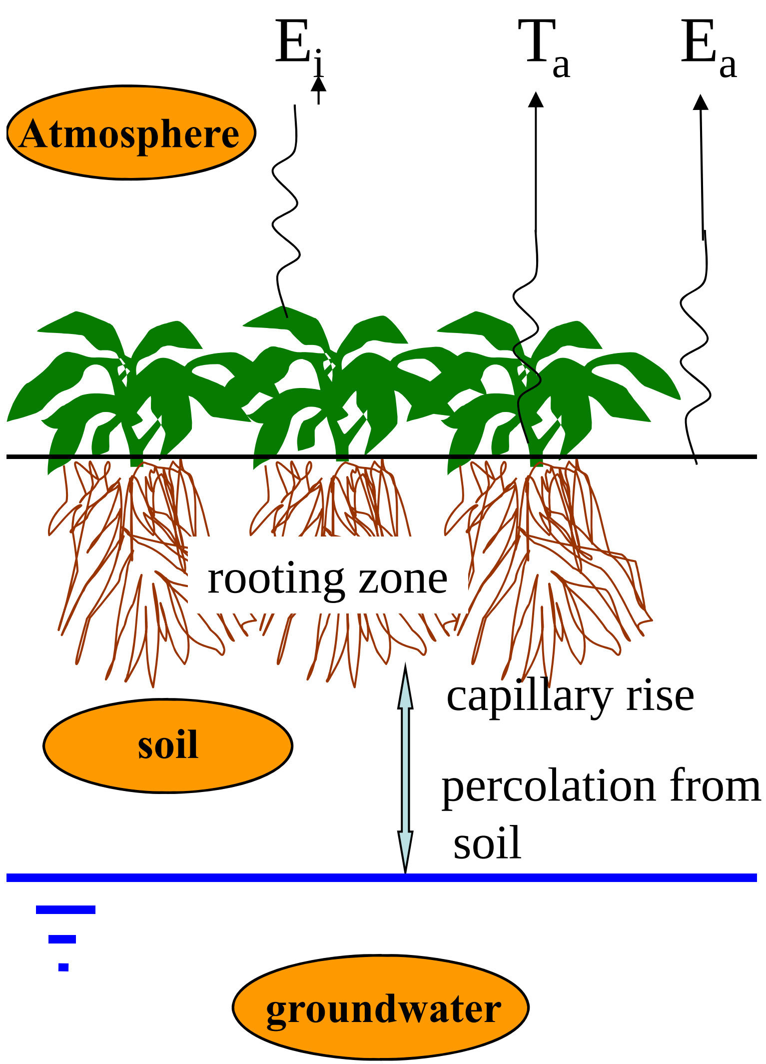
Simulation model

Actual Evapotranspiration EIT_a



PROCESSES:

- **Rainfall**
- **Interception**
- **Run-off**
- **snow layer**
- **Infiltration resp. Evaporation**
- **Water uptake by plant roots (Transpiration)**
- **water flow in soils**
- **evt. preferential water flow**
- **capillary rise**

Simulation

- actual Evapotranspiration EIT_a (= $E_i + E_a + T_a$)
- percolation rate q(z,t)
- volumetric water content θ(z,t) und matric potentials ψ(z,t)

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Input data for the simulation of soil water dynamics:

meteo:
- rainfall
- radiation of sunshine duration
- wind speed
- air temperature → in 2m height
- air humidity

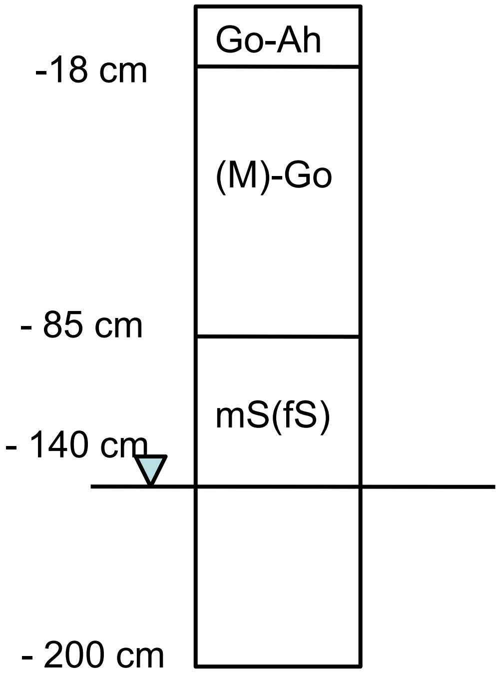
Crop/Vegetation:
- soil cover
- vegetation height
- rooting depth
- root distribution
- leaf area index
- crop/vegetation specific resistance to water flow in plants

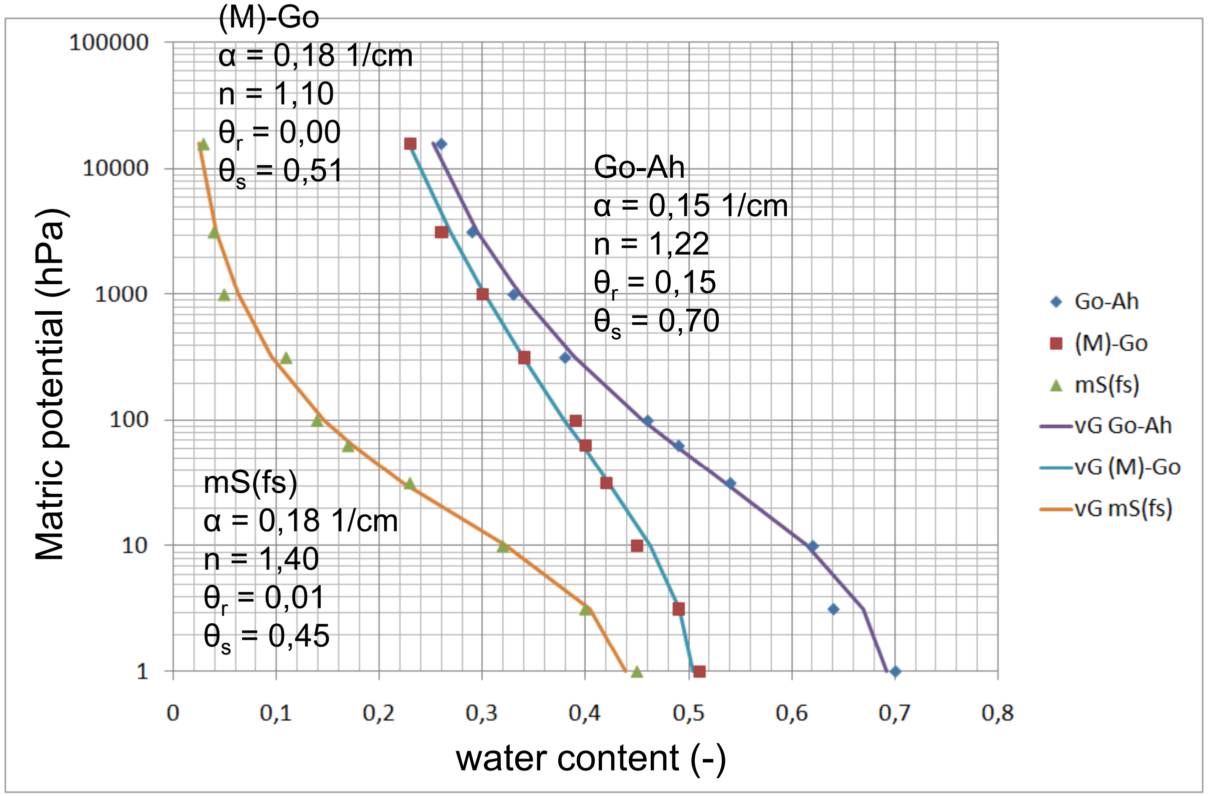
Site specific soil properties of soil horizons:
- water retention curve $\Psi(\theta)$
- unsaturated hydraulic conductivity $k(\theta)$

And
initial conditions: water content $\theta(z,t=0)$
or matric potentials $\psi(z,t=0)$

Groundwater (lower boundary):
- groundwater level in time

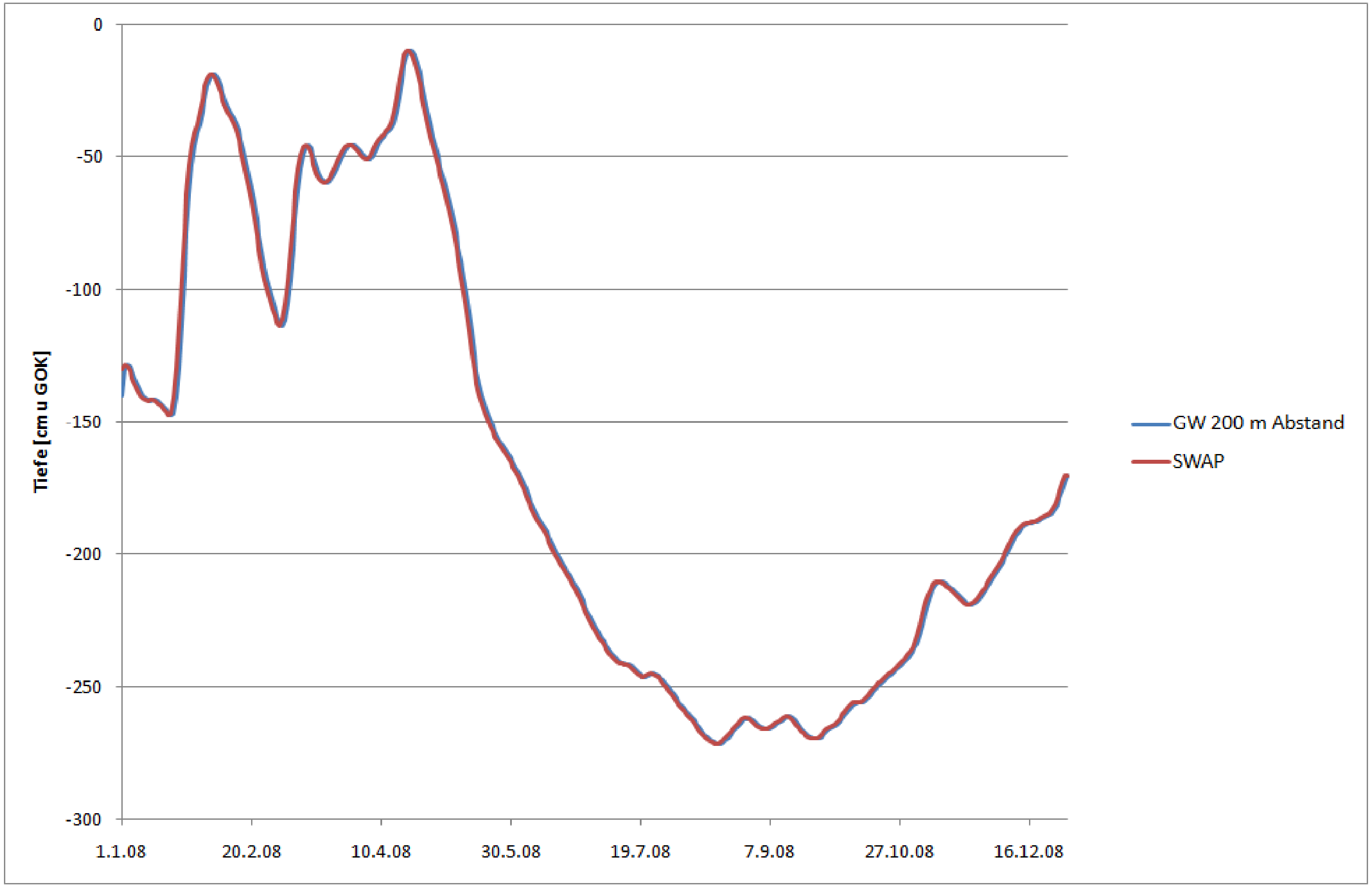
Soil water dynamics in a soil under grassland



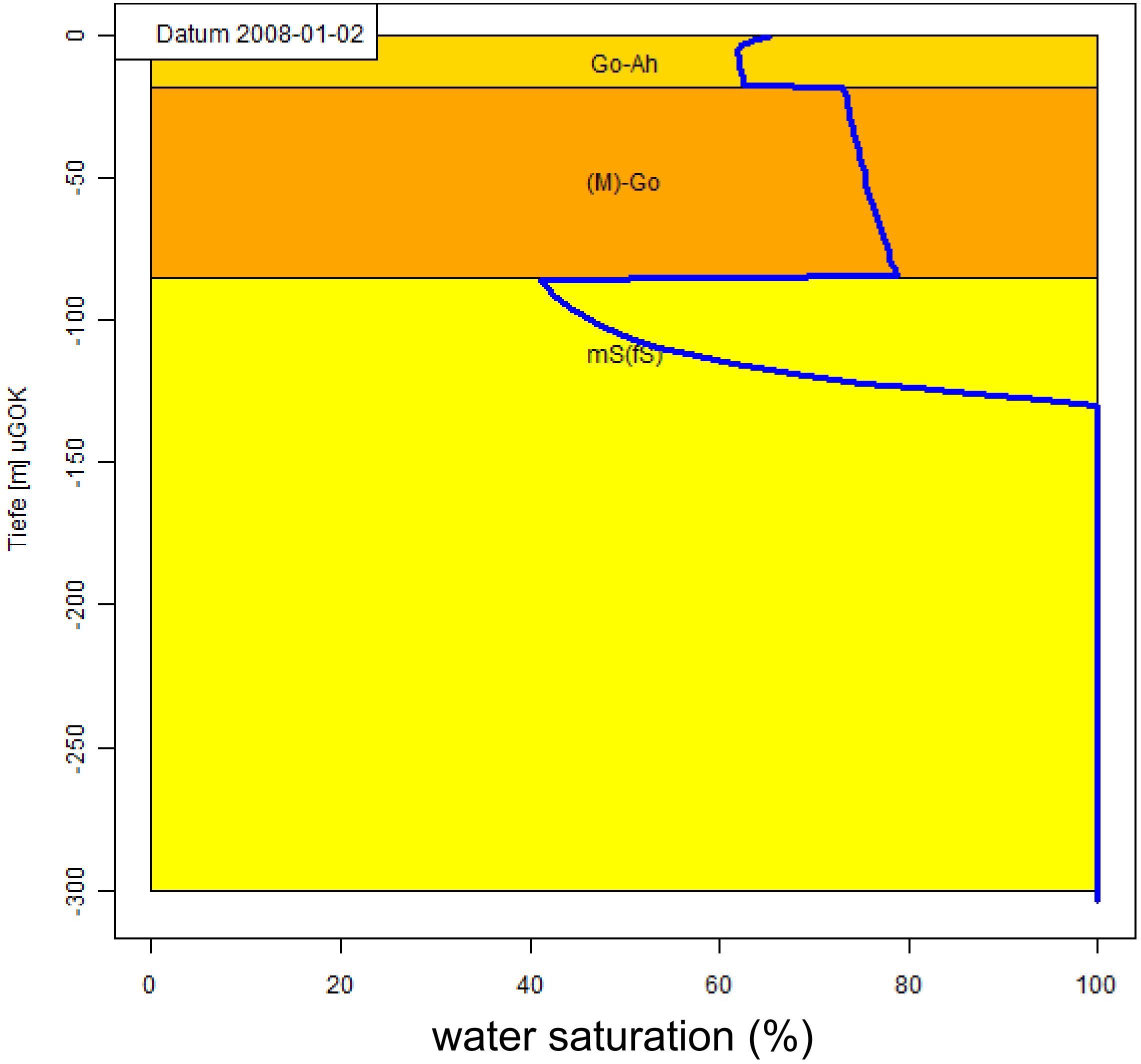


Saturated hydraulic conductivity
Go-Ah: Kfs = 86 cm/d, l = 0,5
(M)-Go: Kfs = 48 cm/d, l = 0,5
mS(fs): Kfs = 660 cm/d, l = 0,5

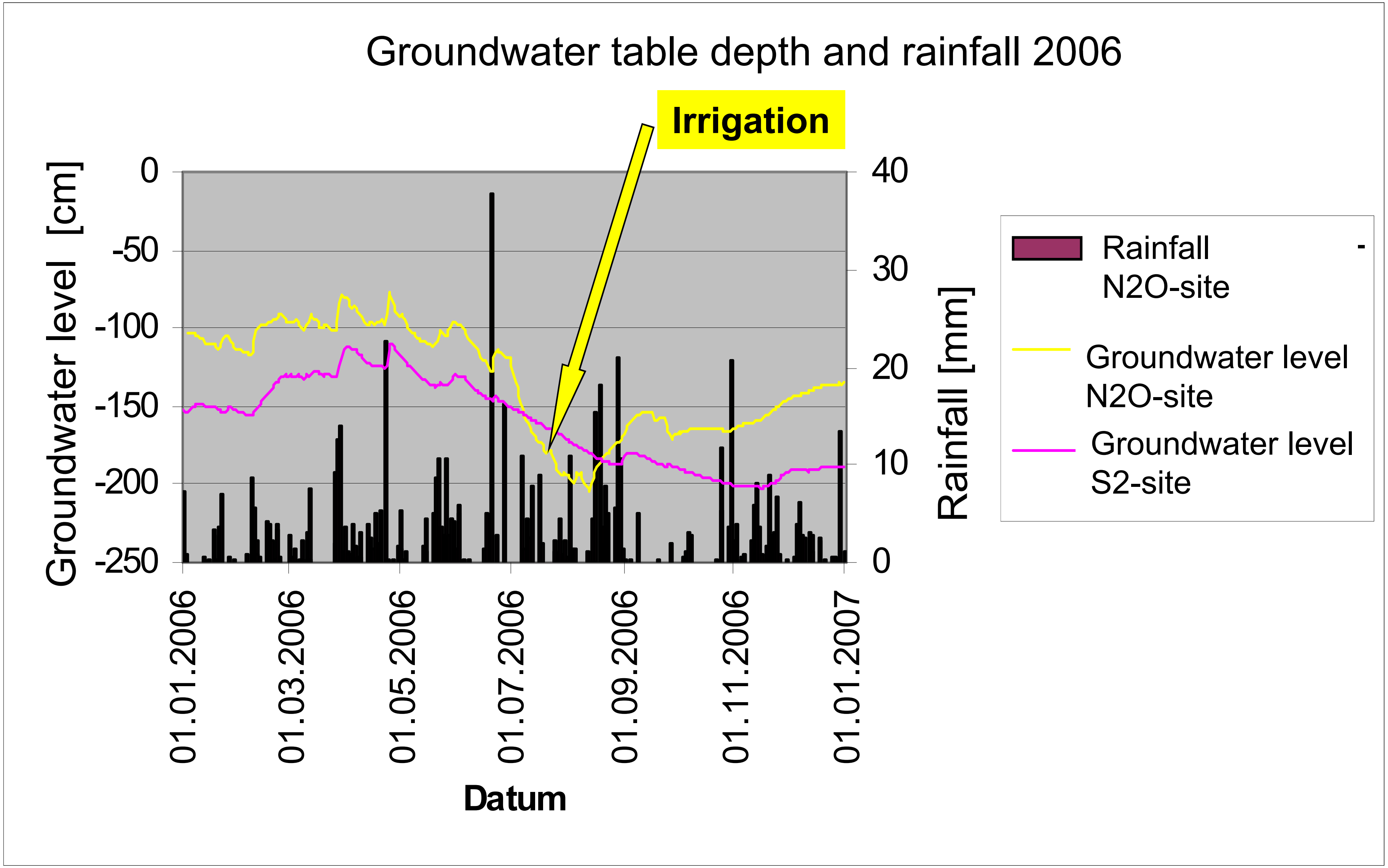
Depth of groundwater tabel below soil surface (cm)



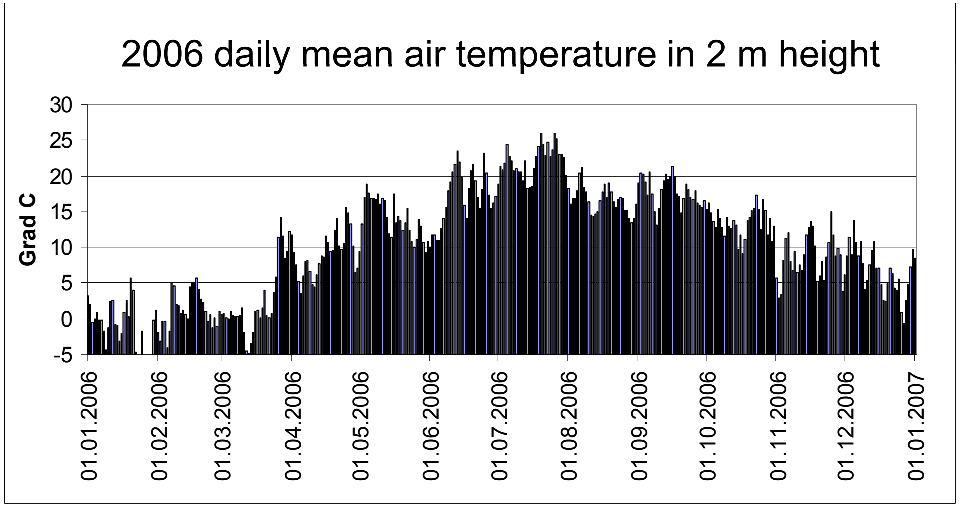
Soil water dynamics in a soil under grassland

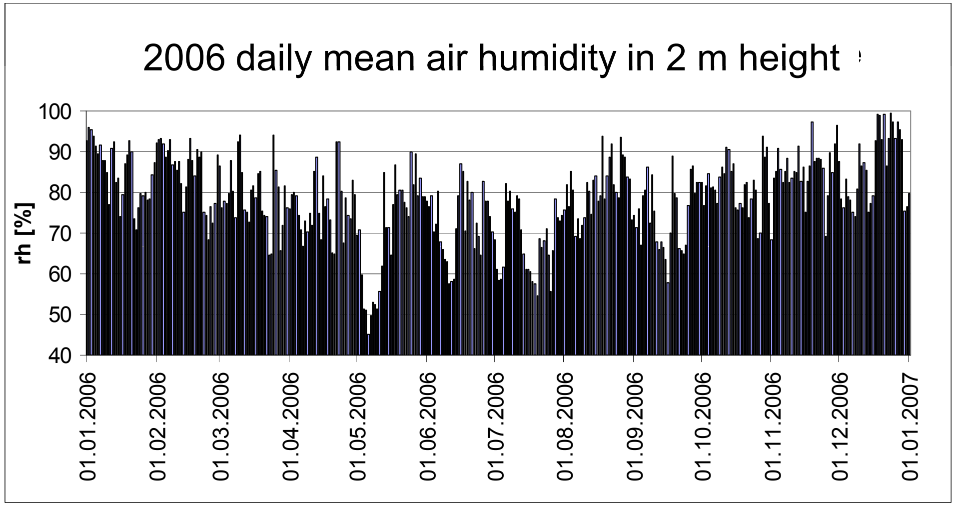


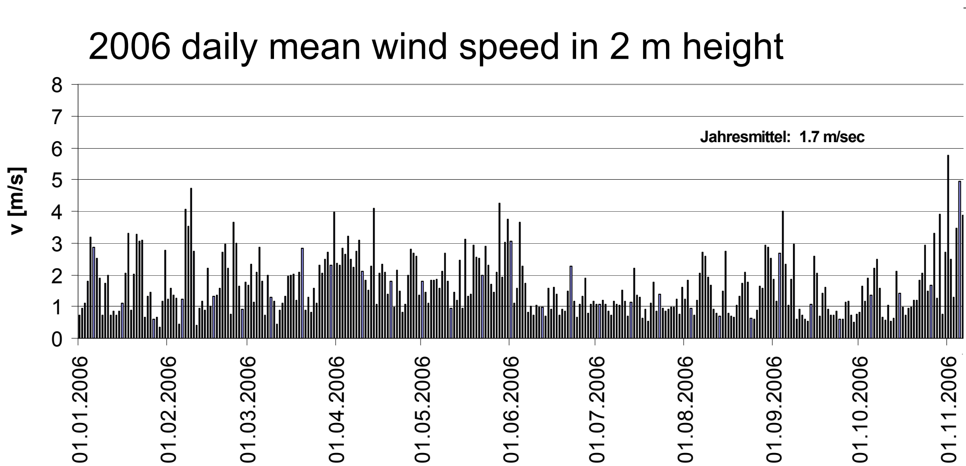
(Palm, 2010)

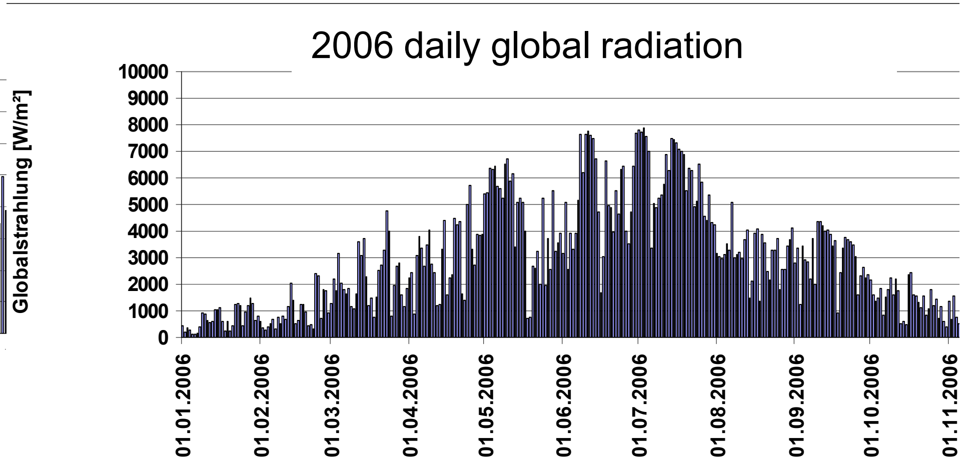

Groundwater table depth and rainfall 2006
Irrigation
Groundwater level [cm]
0
-50
-100
-150
-200
-250
Rainfall [mm]
40
30
20
10
0
01.01.2006
01.03.2006
01.05.2006
01.07.2006
01.09.2006
01.11.2006
01.01.2007
Datum
Rainfall N2O-site
Groundwater level N2O-site
Groundwater level S2-site

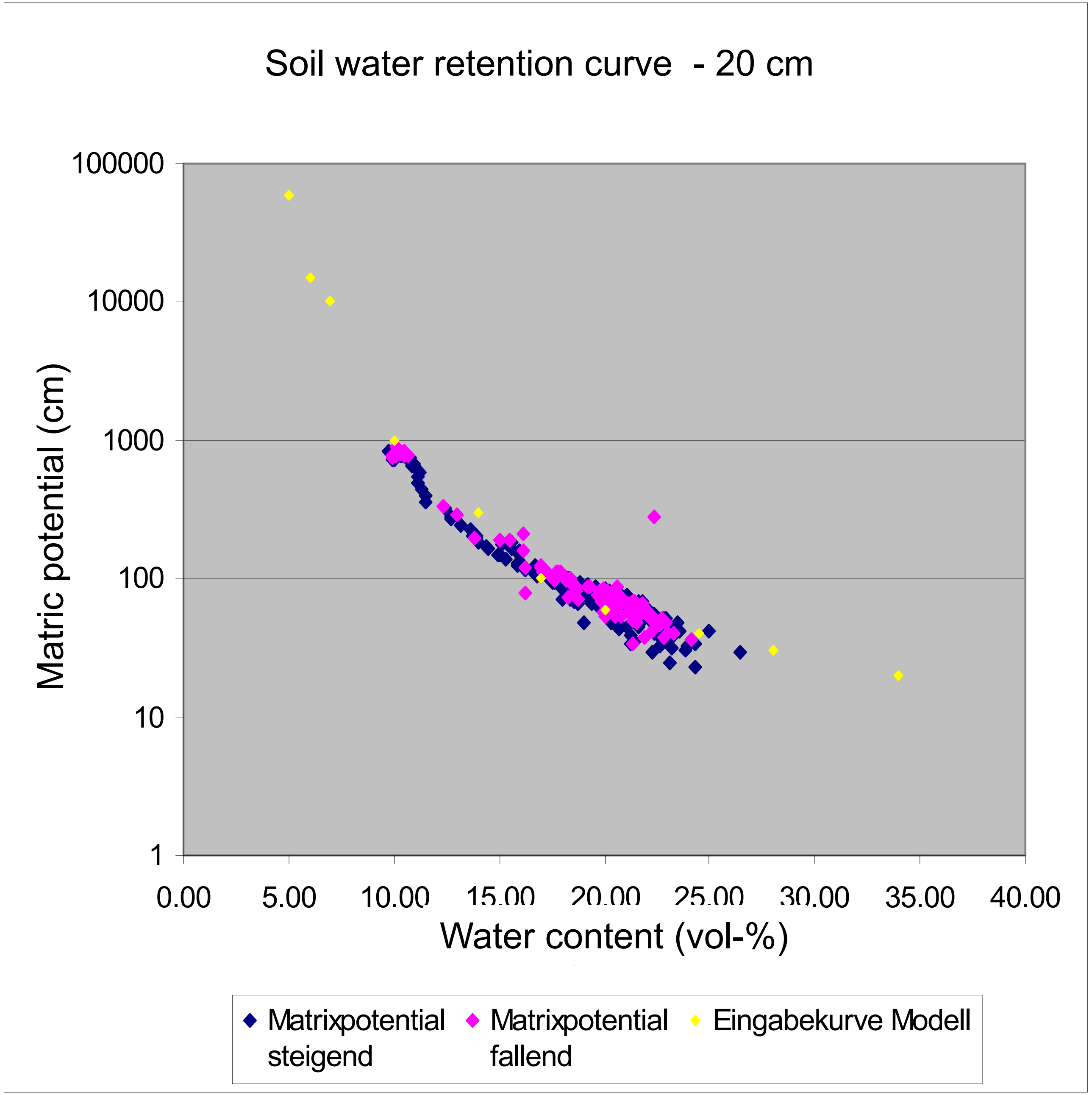
Meteorological data S2



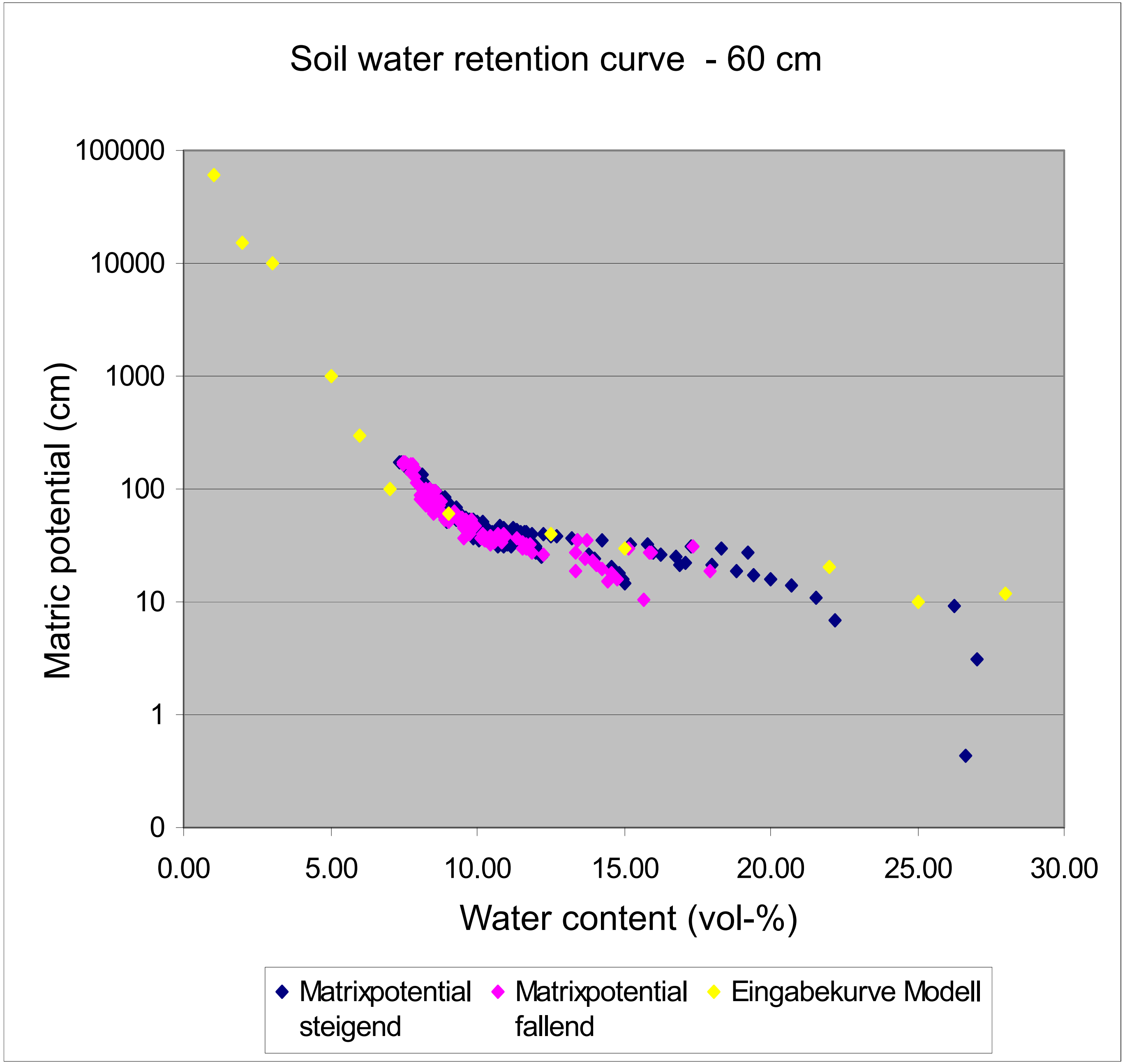




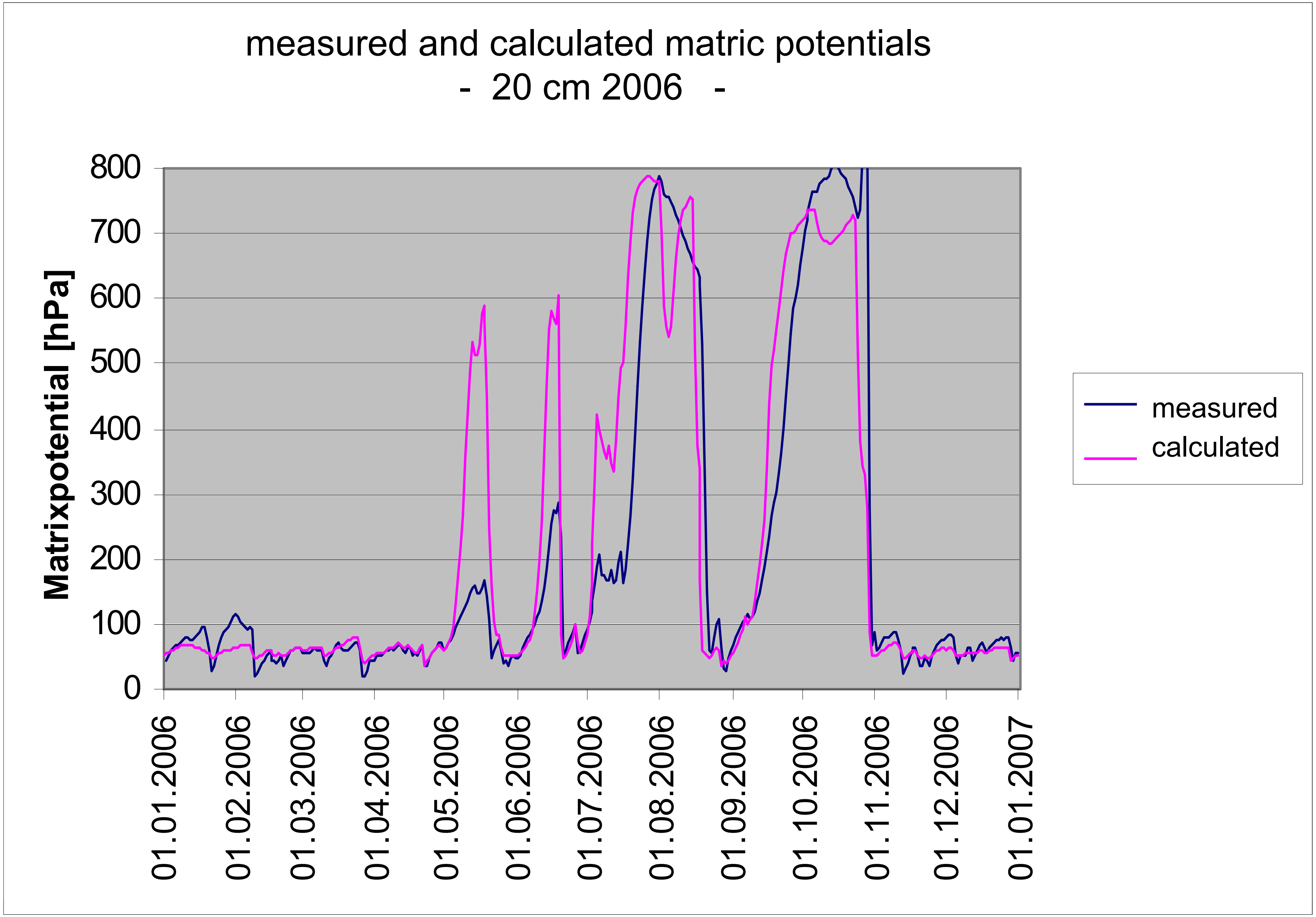


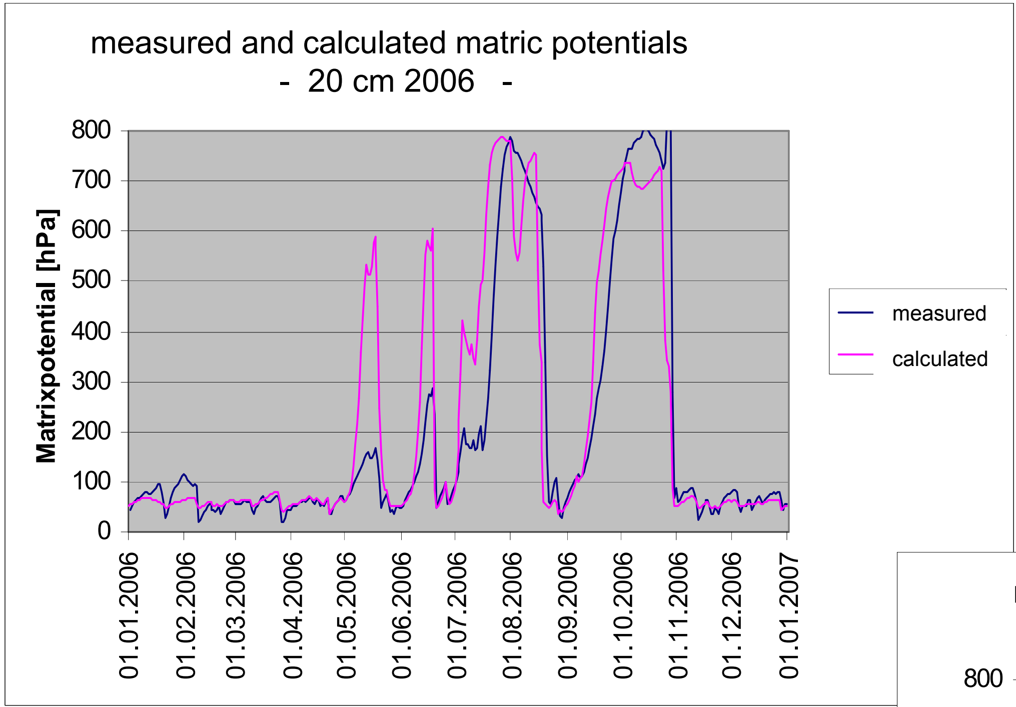


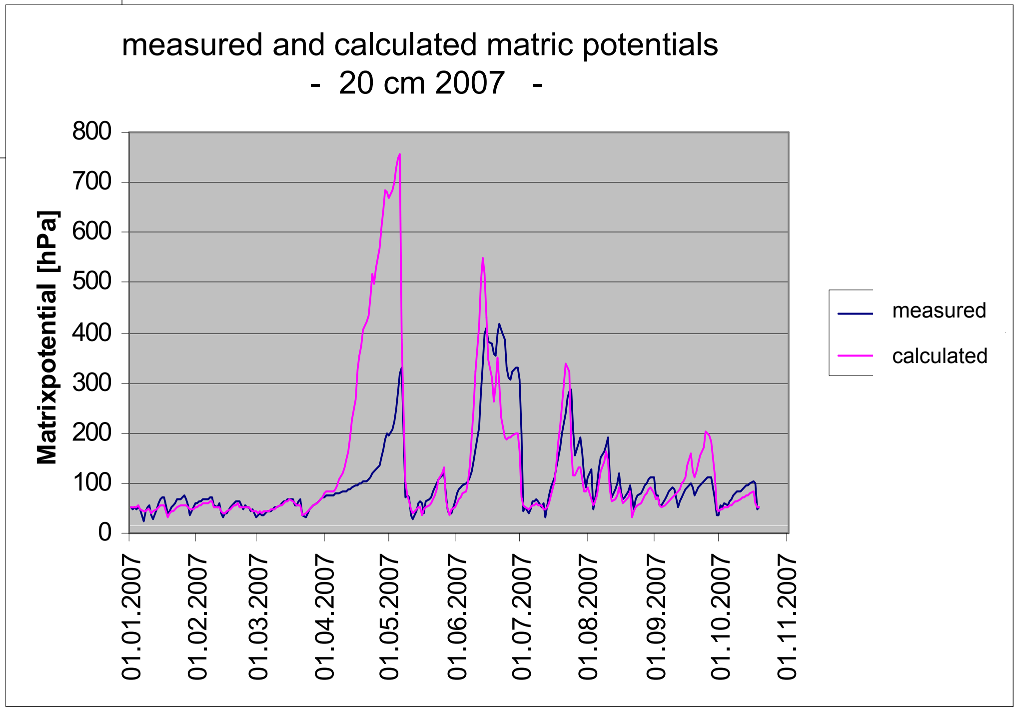
Soil water retention curve - 20 cm
100000
10000
1000
100
10
1
Matric potential (cm)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Water content (vol-%)
Matrixpotential steigend
Matrixpotential fallend
Eingabekurve Modell

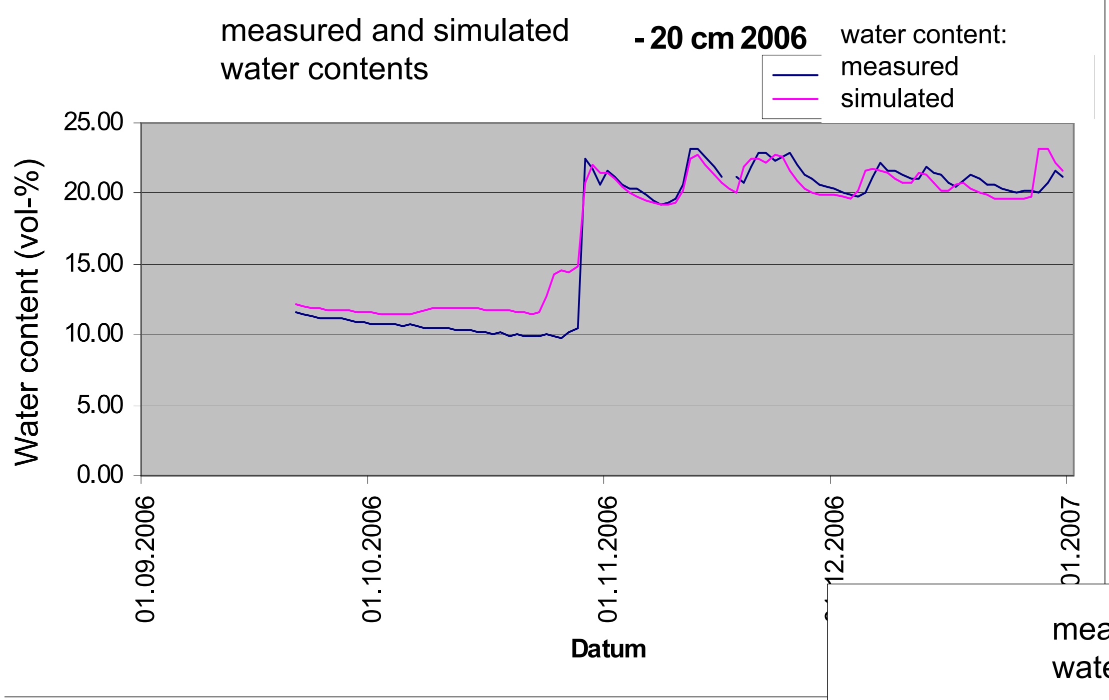


Soil water retention curve - 60 cm
Matric potential (cm)
100000
10000
1000
100
10
1
0
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Water content (vol-%)
Matrixpotential steigend
Matrixpotential fallend
Eingabekurve Modell

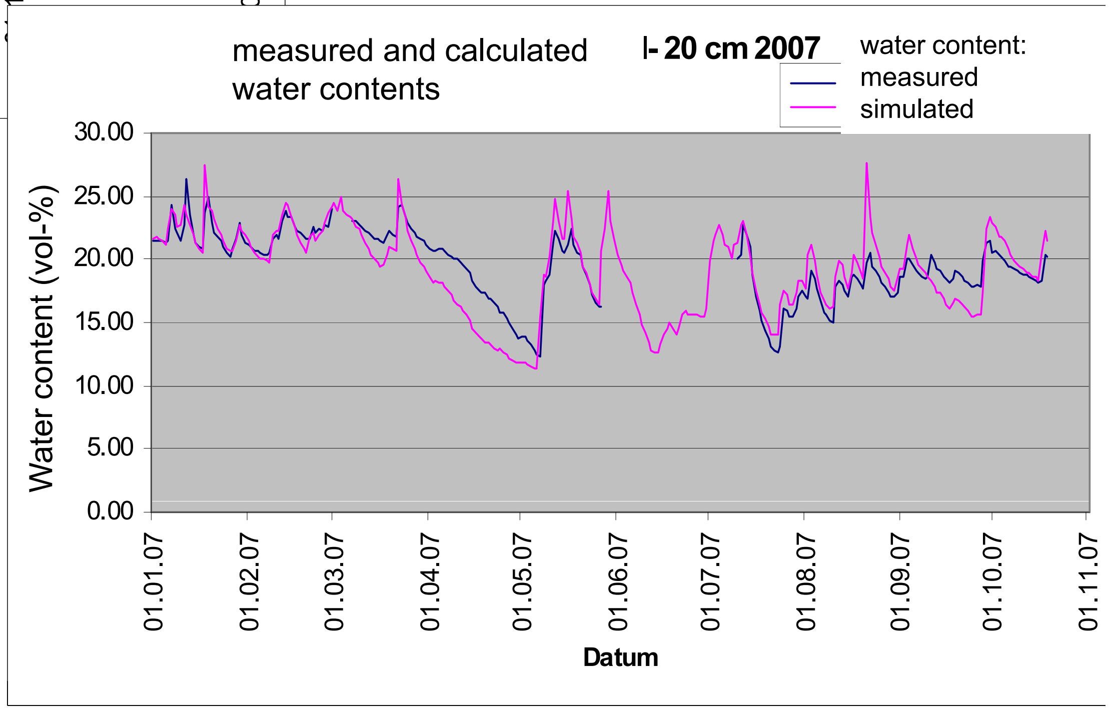

measured and calculated matric potentials
- 20 cm 2006 -
Matrixpotential [hPa]
800
700
600
500
400
300
200
100
0
01.01.2006
01.02.2006
01.03.2006
01.04.2006
01.05.2006
01.06.2006
01.07.2006
01.08.2006
01.09.2006
01.10.2006
01.11.2006
01.12.2006
01.01.2007
measured
calculated


measured and calculated matric potentials
- 20 cm 2006 -
Matrixpotential [hPa]
800
700
600
500
400
300
200
100
0
01.01.2006
01.02.2006
01.03.2006
01.04.2006
01.05.2006
01.06.2006
01.07.2006
01.08.2006
01.09.2006
01.10.2006
01.11.2006
01.12.2006
01.01.2007
measured
calculated

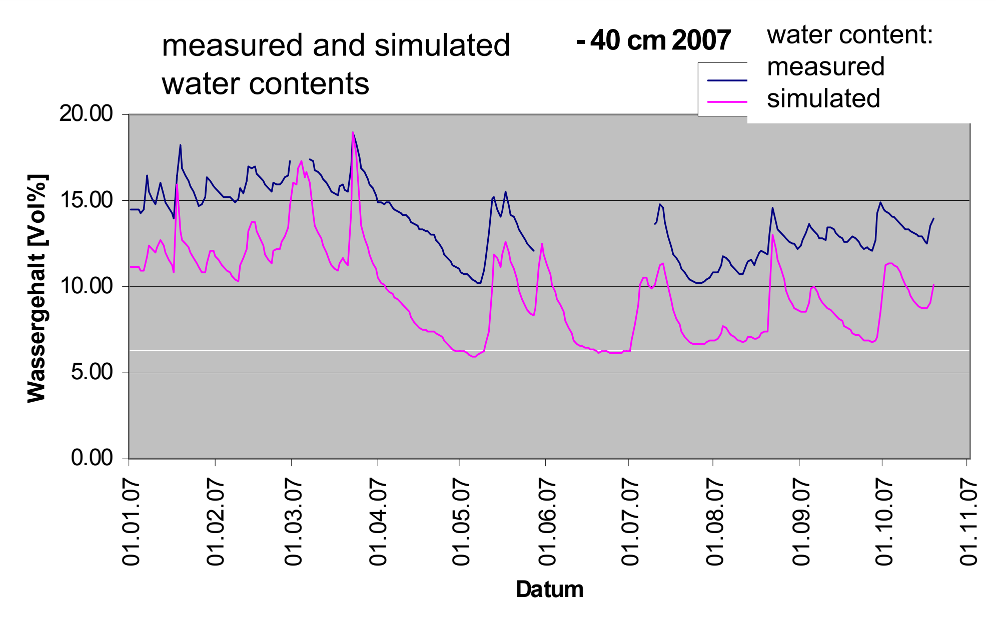

measured and calculated matric potentials
- 20 cm 2007 -
Matrixpotential [hPa]
800
700
600
500
400
300
200
100
0
01.01.2007
01.02.2007
01.03.2007
01.04.2007
01.05.2007
01.06.2007
01.07.2007
01.08.2007
01.09.2007
01.10.2007
01.11.2007
measured
calculated

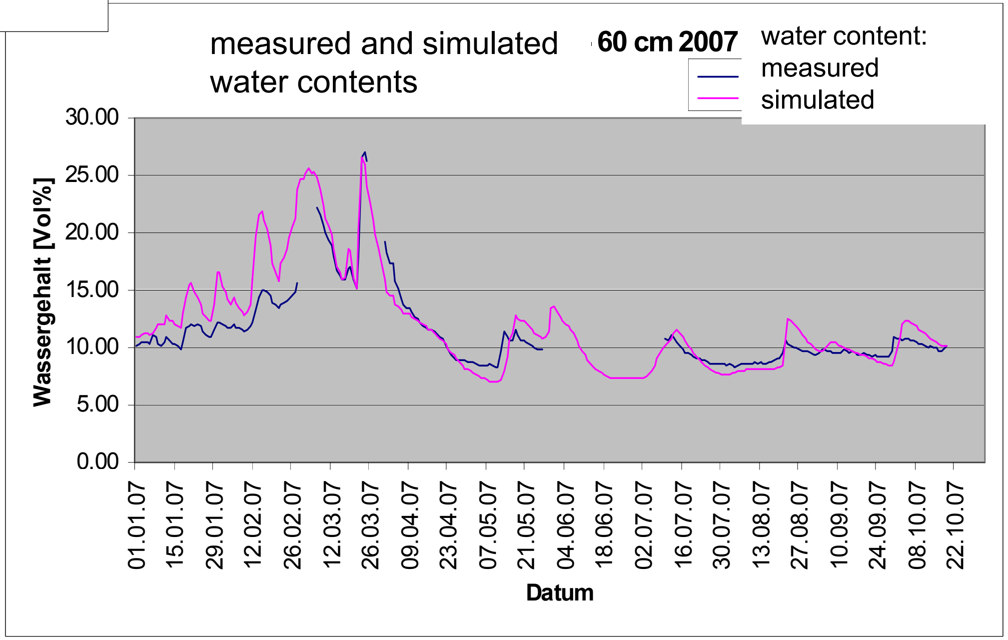


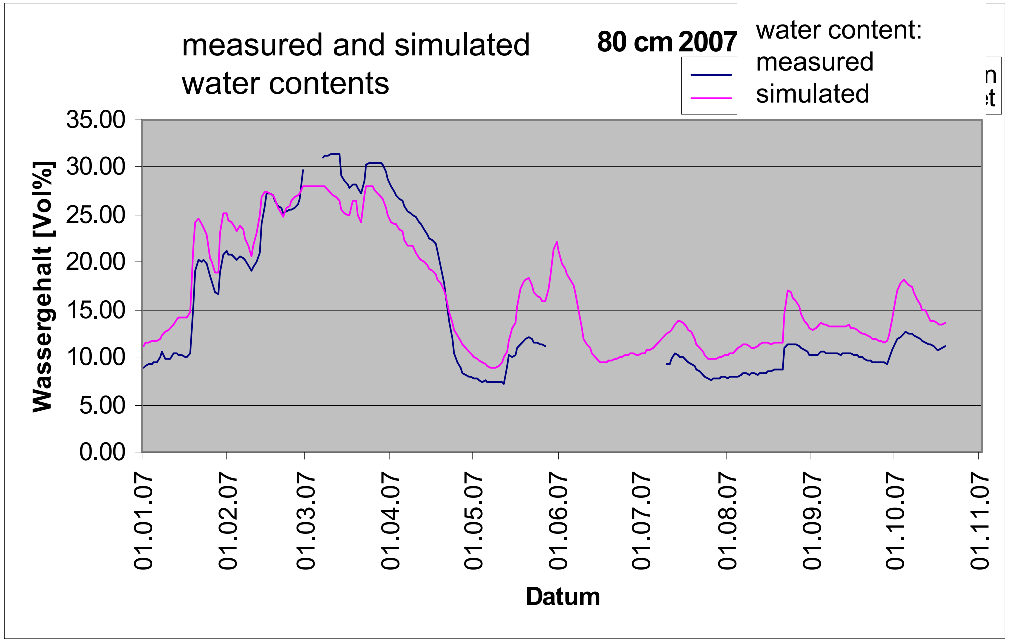
measured and simulated
water contents
- 20 cm 2006
water content:
measured
simulated
Water content (vol-%)
25.00
20.00
15.00
10.00
5.00
0.00
01.09.2006
01.10.2006
01.11.2006
Datum

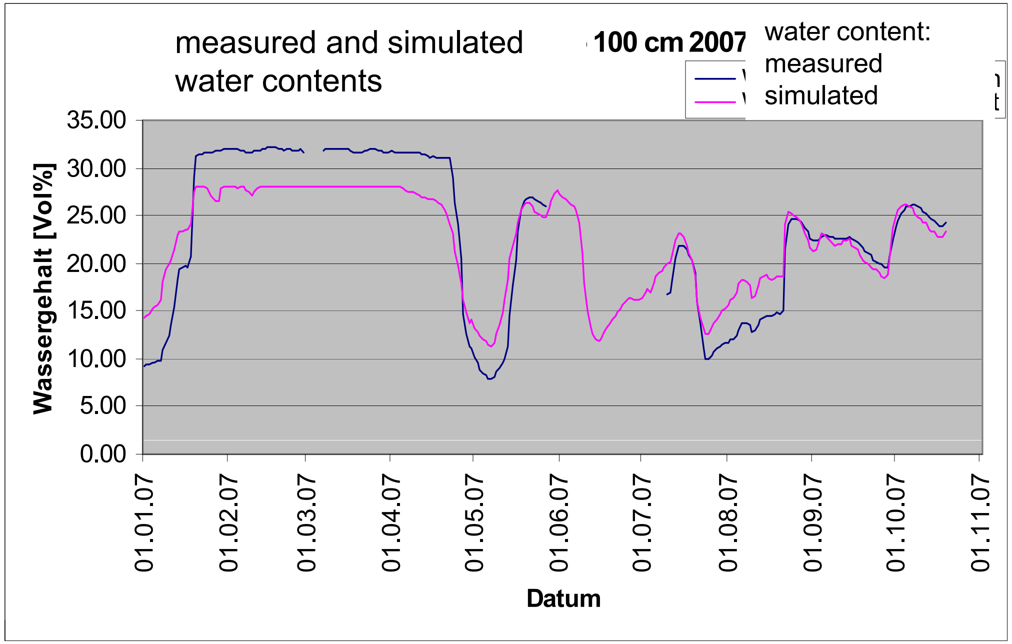


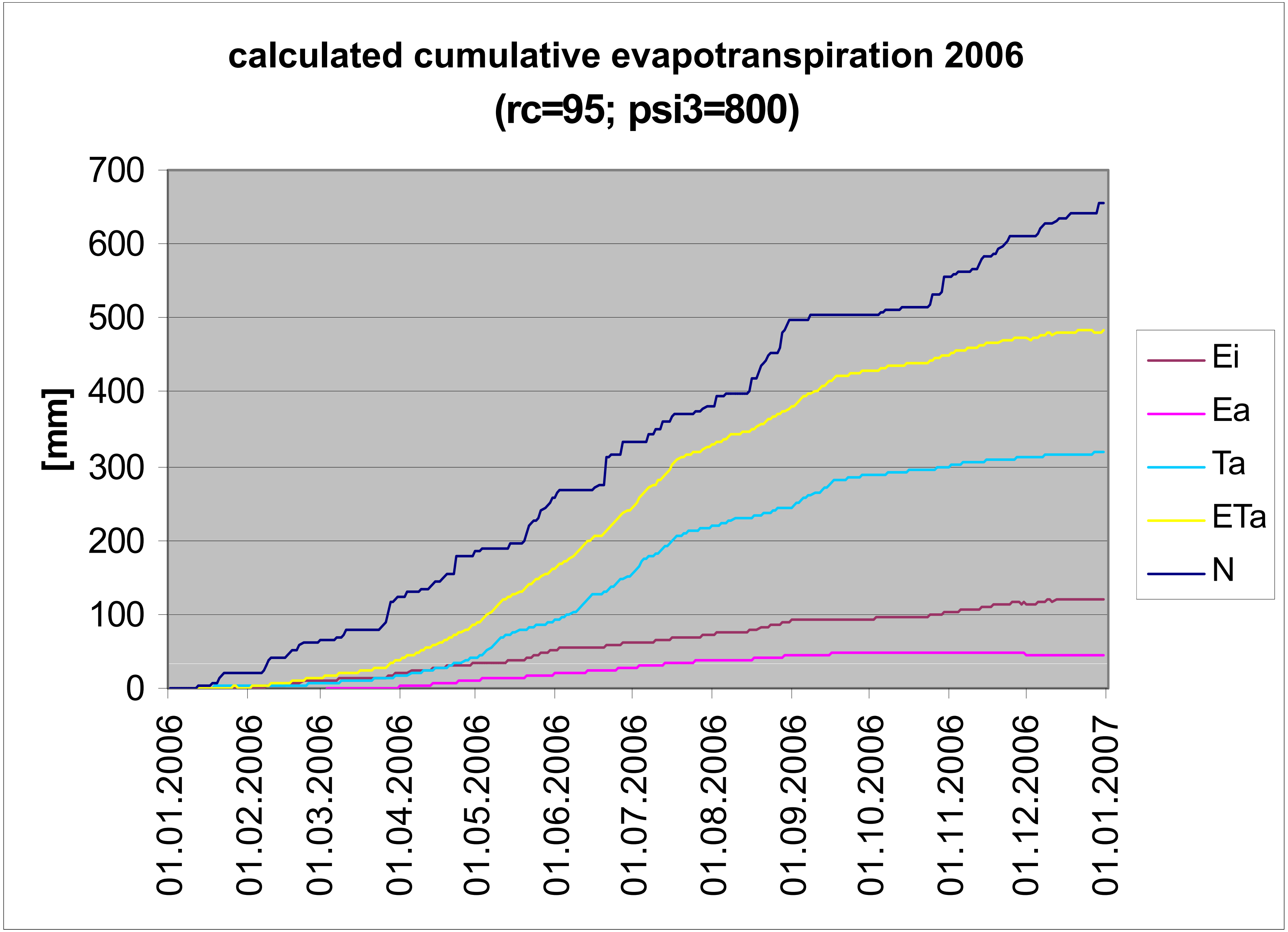
measured and calculated
water contents
I- 20 cm 2007
water content:
measured
simulated
Water content (vol-%)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
01.01.07
01.02.07
01.03.07
01.04.07
01.05.07
01.06.07
01.07.07
01.08.07
01.09.07
01.10.07
01.11.07
Datum

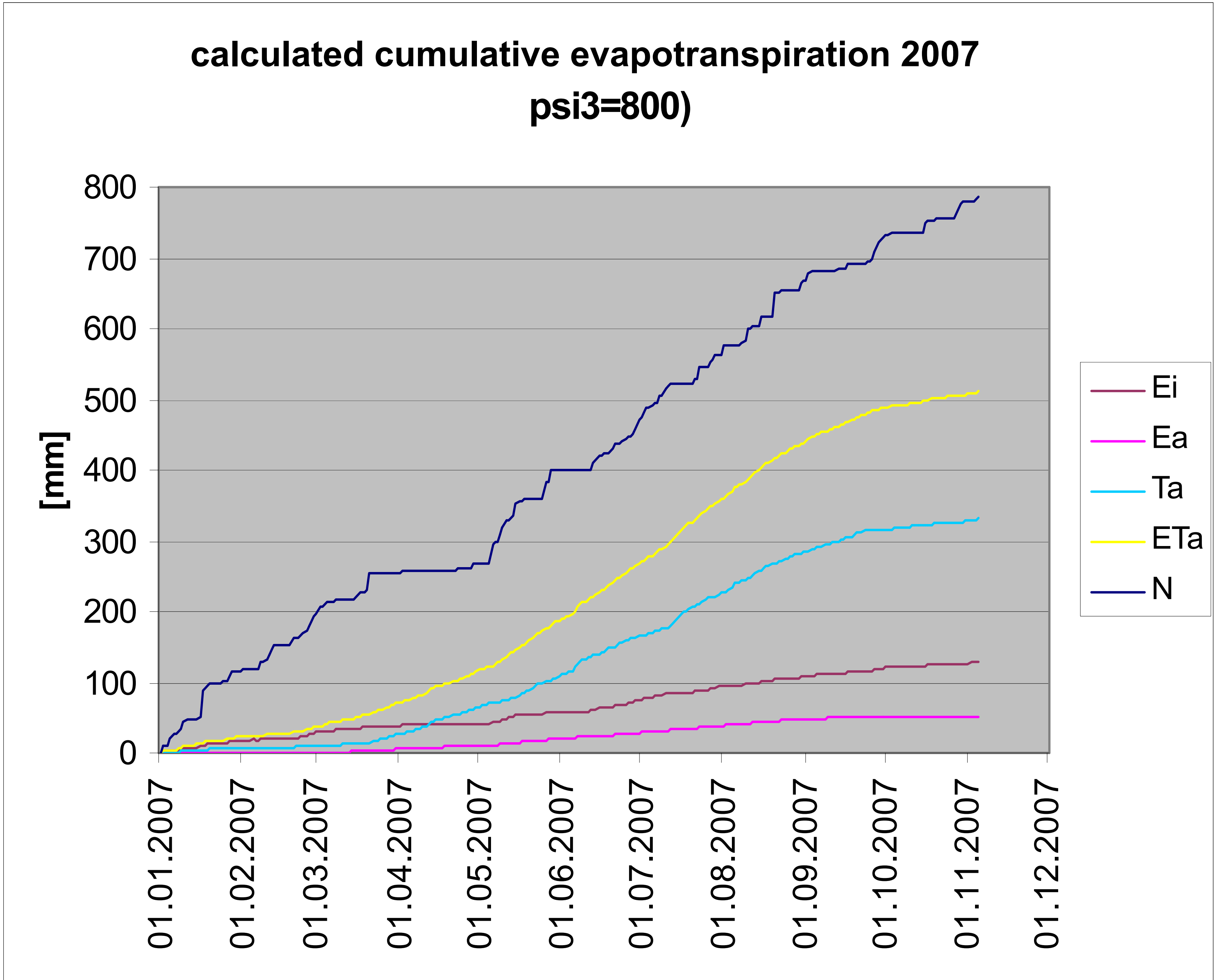

measured and simulated water contents
- 40 cm 2007
water content:
measured
simulated
Wassergehalt [Vol%]
20.00
15.00
10.00
5.00
0.00
01.01.07
01.02.07
01.03.07
01.04.07
01.05.07
01.06.07
01.07.07
01.08.07
01.09.07
01.10.07
01.11.07
Datum


measured and simulated water contents
60 cm 2007
water content:
measured
simulated
Wassergehalt [Vol%]
30.00
25.00
20.00
15.00
10.00
5.00
0.00
01.01.07
15.01.07
29.01.07
12.02.07
26.02.07
12.03.07
26.03.07
09.04.07
23.04.07
07.05.07
21.05.07
04.06.07
18.06.07
02.07.07
16.07.07
30.07.07
13.08.07
27.08.07
10.09.07
24.09.07
08.10.07
22.10.07
Datum


measured and simulated water contents
80 cm 2007
water content:
measured
simulated
Wassergehalt [Vol%]
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
01.01.07
01.02.07
01.03.07
01.04.07
01.05.07
01.06.07
01.07.07
01.08.07
01.09.07
01.10.07
01.11.07
Datum


measured and simulated water contents
100 cm 2007
water content:
measured
simulated
Wassergehalt [Vol%]
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
01.01.07
01.02.07
01.03.07
01.04.07
01.05.07
01.06.07
01.07.07
01.08.07
01.09.07
01.10.07
01.11.07
Datum


calculated cumulative evapotranspiration 2006
(rc=95; psi3=800)
[mm]
700
600
500
400
300
200
100
0
01.01.2006
01.02.2006
01.03.2006
01.04.2006
01.05.2006
01.06.2006
01.07.2006
01.08.2006
01.09.2006
01.10.2006
01.11.2006
01.12.2006
01.01.2007
Ei
Ea
Ta
ETa
N

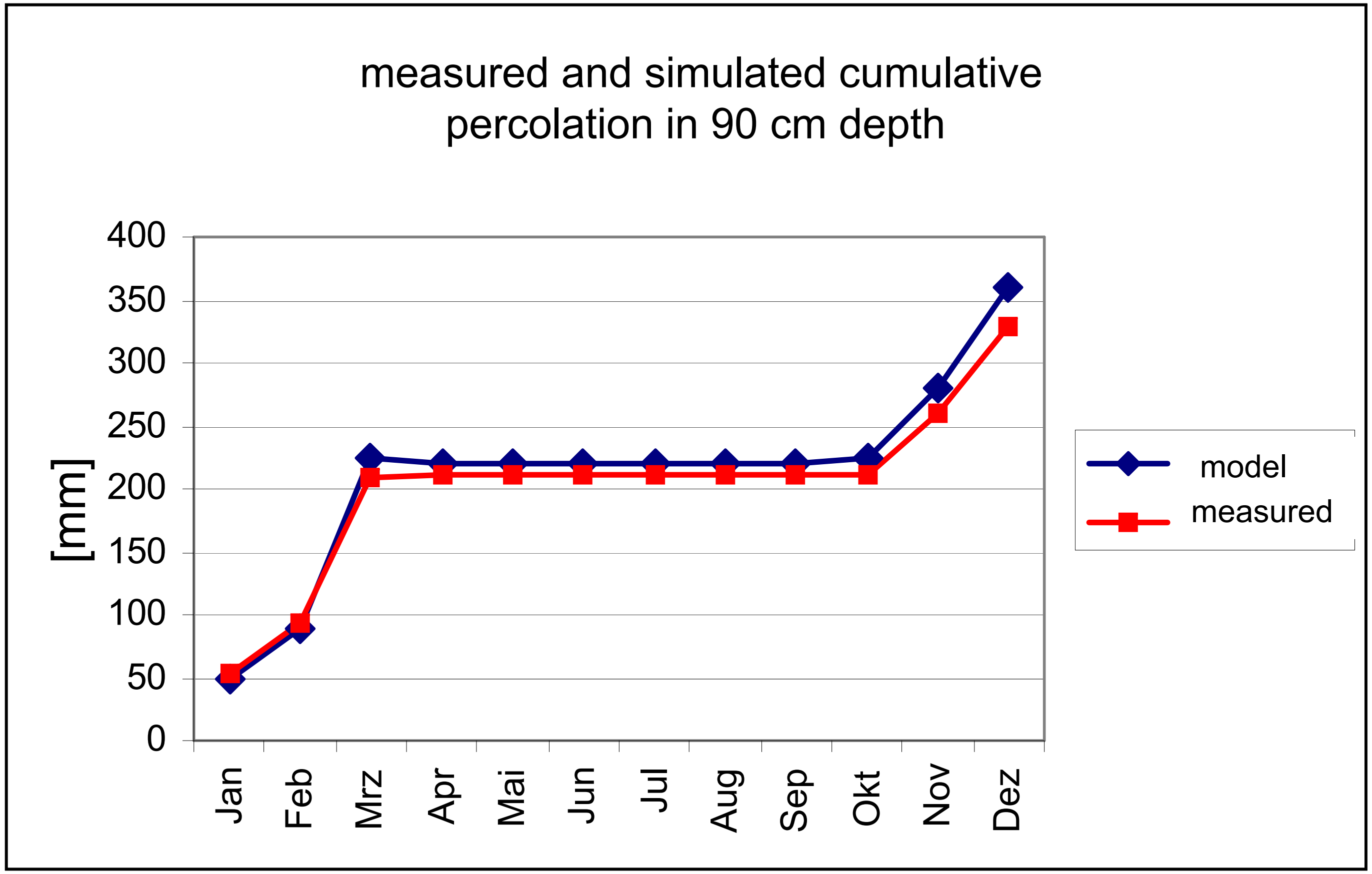


calculated cumulative evapotranspiration 2007
psi3=800)
800
700
600
500
400
300
200
100
0
[mm]
01.01.2007
01.02.2007
01.03.2007
01.04.2007
01.05.2007
01.06.2007
01.07.2007
01.08.2007
01.09.2007
01.10.2007
01.11.2007
01.12.2007
Ei
Ea
Ta
ETa
N

Case study Fuhrberger Feld, arable land:

- Podsol (deep GW-table) in fine sandy medium sands (mSfs)
- sugar beets 1988
- groundwater levels: > 2.5 m

Compare model results with field measurements



Difference measured-simulated Δ ≈ 10%

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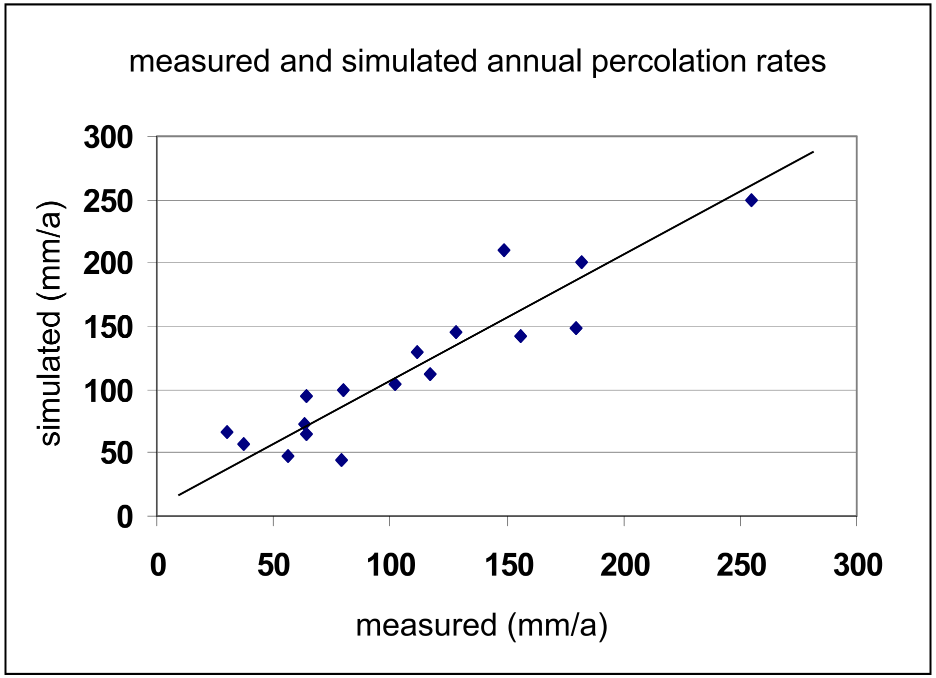
Calibration and validation of the soil water dynamic model



<u>Validated simulation model for different:</u>

- soils
- vegetation
- climatic regions
- groundwater table depth

- case studies e.g. suppl. irrigation
- long term mean annual percolation rate

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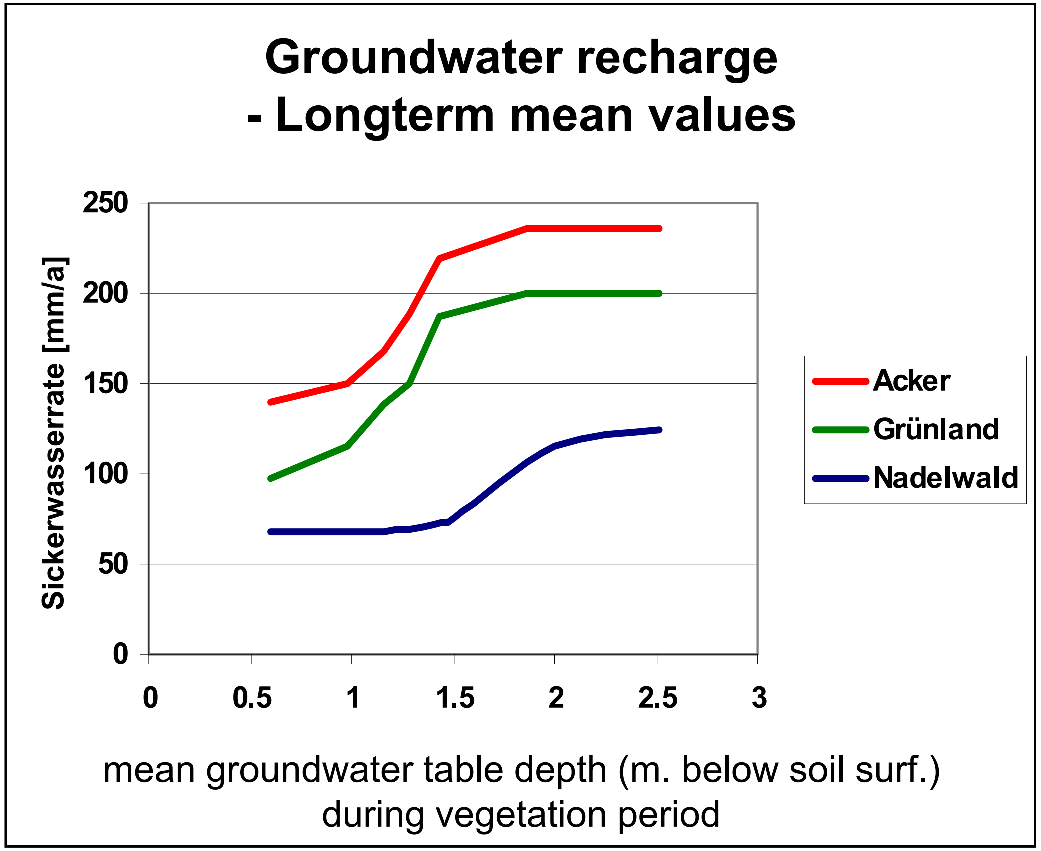
Groundwater recharge from soil :

long term mean values calculated with a soil water dynamic model

- Example Fuhrberger Feld: annual rainfall = 680 mm/a
- Soil: Gley-Podsol of fsmS nFKWe: arable land / grasland = 70 mm
  forest = 100 mm

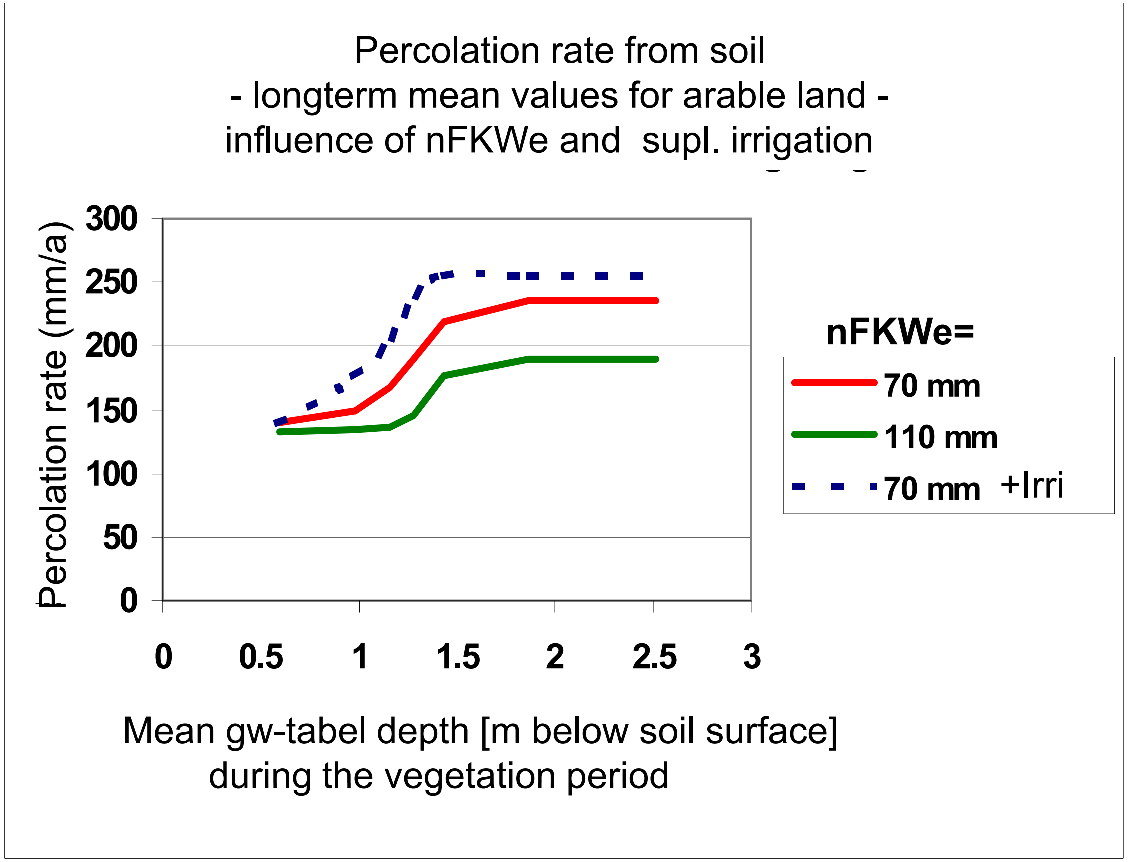


= Arable land
= Grassland
= Coniferous forest

Influence of nFKWe (PAW_{root}) and Irrigation on percolation rate :

longterm mean values simulated with a soil water dynamics model

- **Example North Hannover: mean precipitation = 680 mm/a**
- **different soils: nFKWe: arable land = 70 mm (with and without supl. irrigation)**
  = 110 mm



Suppl. Irrigation with deep gw-table
=
ca. 60- 120 mm/a depends on crop

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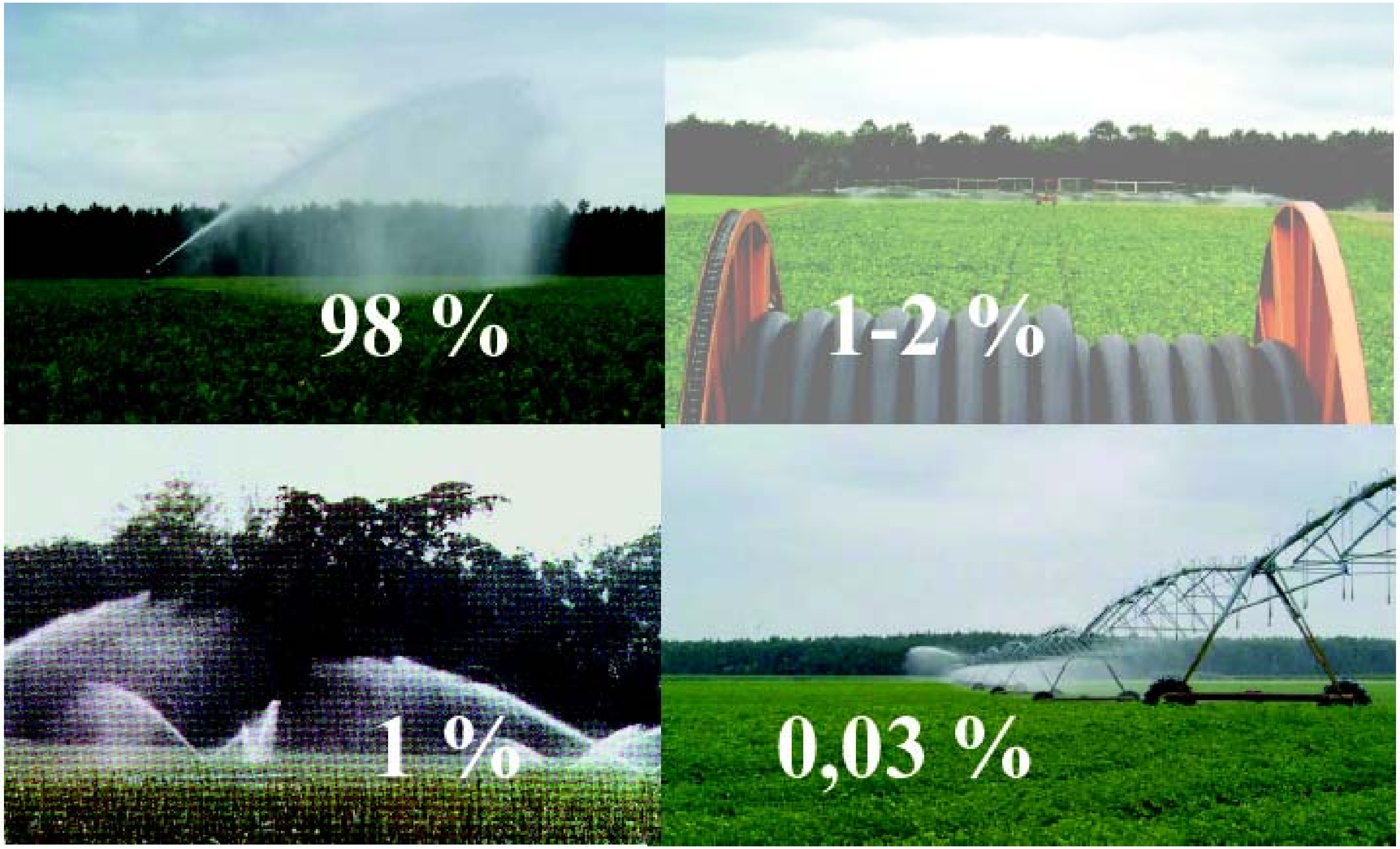
Supplemental irrigation in northern Germany



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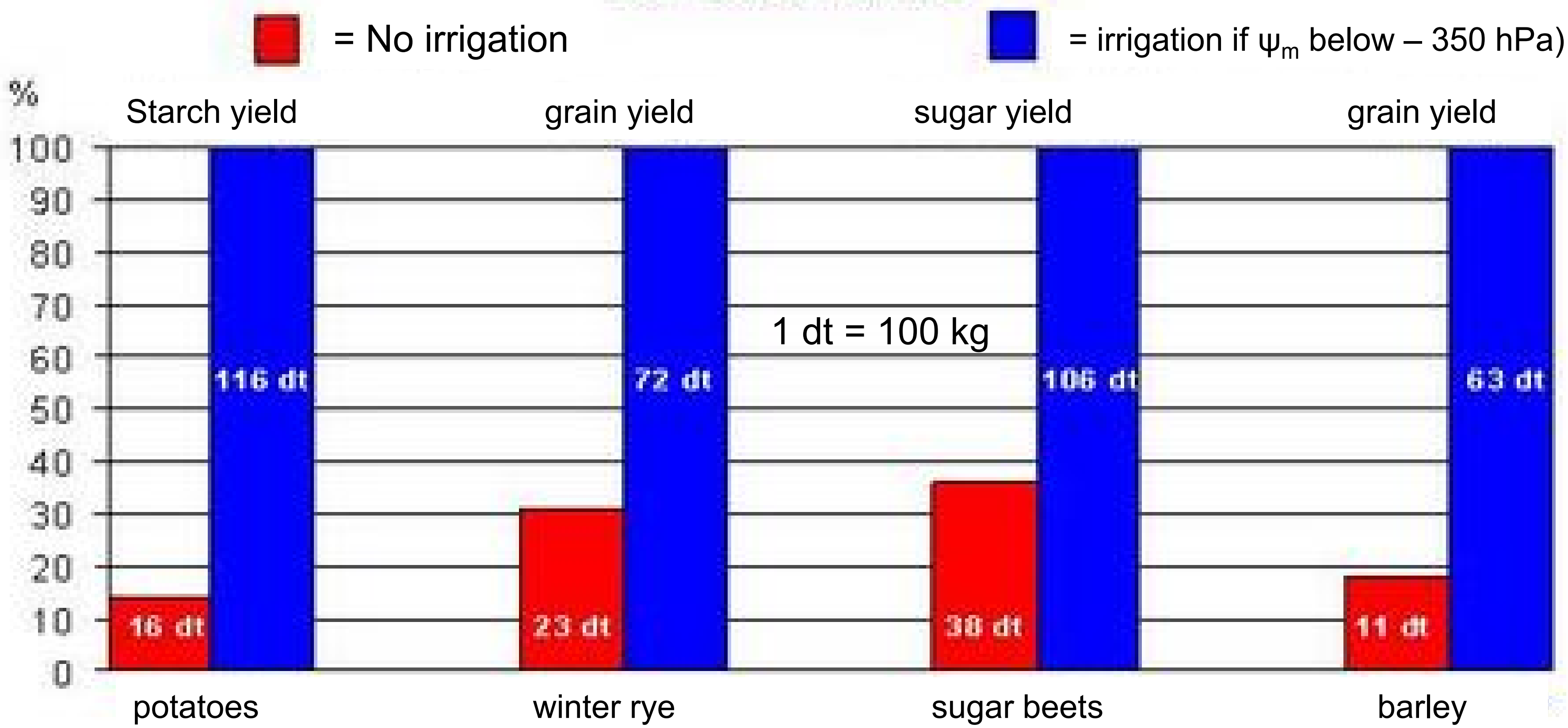
Effect of supplemental irrigation on crop yield in 2003



amount of applied supplemetal irrigation

potatoes	winter rye	sugar beets	barley
290	139	244	181

-Max. allowed supplemetal irrigation = 560 mm/(7years)

-Low yield posible higher leaching of plant nutrients like nitrate

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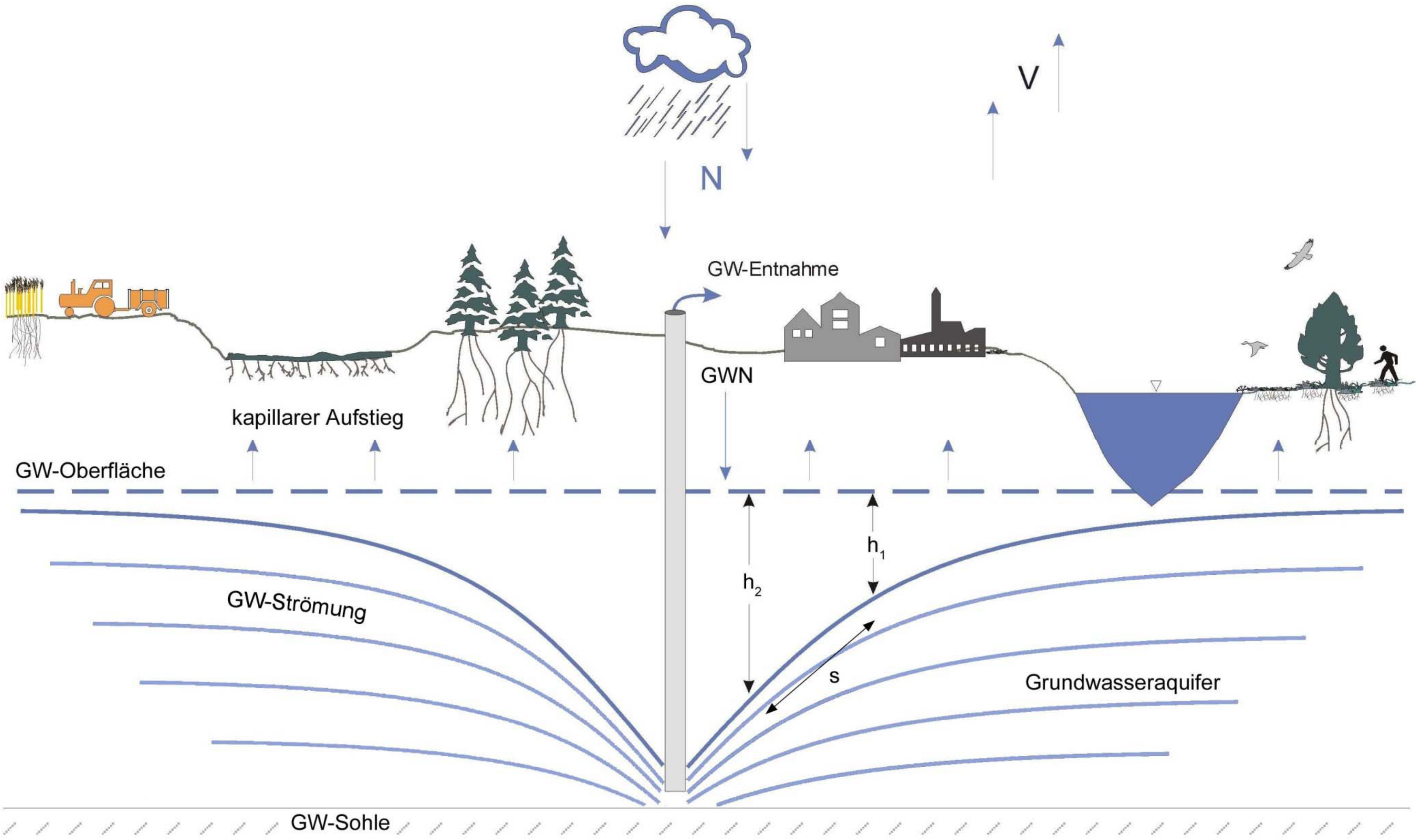
Groundwater extraction



→ Water table drawdown → Irrigation, grassland plowing

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Supplemental irigation area in Germany 2001

Bundesland	Agricultural area ha of LF	Irrigated area ha	Irrigated area % der LF
Bayern	3.381.400	35.000	1,04
Baden-Württemberg	1.460.300	20.000	1,37
Berlin (West)	1.500	200	13,33
Brandenburg	1.298.400	25.000	1,93
Hessen	786.300	45.000	5,72
Mecklenburg-Vorpommern	1.313.200	15.000	1,14
Niedersachsen	2.714.100	235.000	8,66
Nordrhein-Westfalen	1.565.000	35.000	2,24
Rheinland-Pfalz	714.300	25.800	3,61
Saarland	73.500	170	0,23
Sachsen	898.100	15.000	1,67
Sachsen-Anhalt	1.134.500	20.000	1,76
Schleswig-Holstein	1.055.700	5.450	0,52
Thüringen	788.500	15.000	1,90
Deutschland insgesamt	**17.184.800**	**491.620**	**2,86**

*) Analyse des Bundesfachverbandes Feldberegnung 1995; aktualisiert 2001

1) nach BML / Ref.421 (nur Betriebe über 1ha)

A new method to calculate the annual percolation rate from the soil :

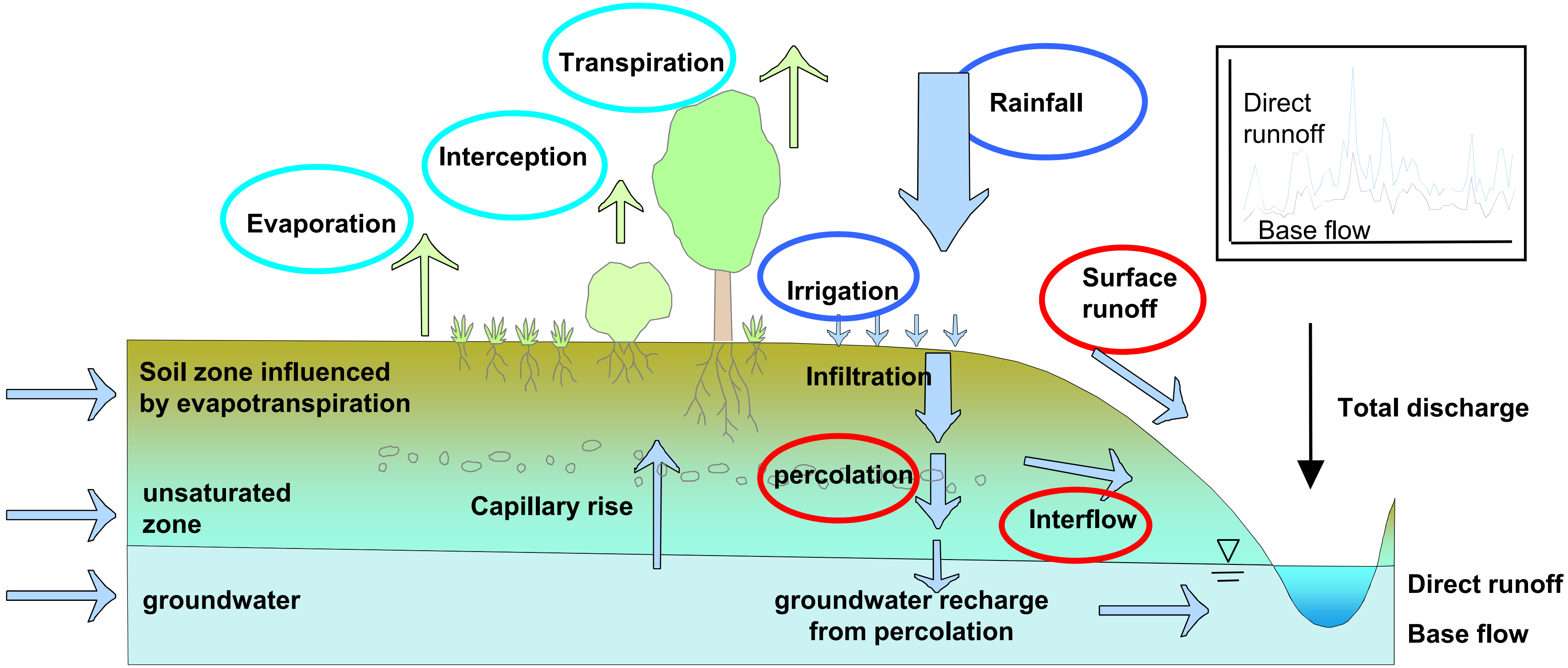
the TUB-BGR-Method

Topics

- method acording to Renger & Wessolek (1990)
- reasons for development
- the new TUB-BGR-Method
- Calculations (simulationmodel)
- new regression equations
- Application and Validation in the HAD (Hydrological Atlas of Germany)

- Exercise with the TUB-BGR-Method

Wessolek, G., W.H.M. Duijnisveld und S. Trinks (2008): Hydro-pedotransfer functions (HPTFs) for predicting the annual percolation rate on a regional scale. Journal of Hydrology, 356: 17-27



annual percolation rate = rainfall – surface runoff – actual evapotranspiration

(= total runoff minus surface runoff)

Annual percolation rate from soil in Germany

Determination of regression equations to calculate the annual percolation rate from easily measurable soil properties and meteorological data

Land use	Regression equations (Renger und Wessolek, 1990)	R
Arable land	$V = 0.92\,(Wj) + 0.61\,(Sj) - 153\,(\log Wpfl) - 0.12\,(E_{HAUDE}) + 109$	0.84
Grassland	$V = 0.90\,(Wj) + 0.52\,(Sj) - 286\,(\log Wpfl) - 0.10\,(E_{HAUDE}) + 330$	0.95
Conf. forest	$V = 0.71\,(Wj) + 0.67\,(Sj) - 166\,(\log Wpfl) - 0.19\,(E_{HAUDE}) + 127$	0.95

V	= percolation rate	mm/a
W_j	= winter rainfall (01.10.-31.03)	mm
S_j	= summer rainfall (01.04. – 30.09.)	mm
Wpfl	= plant available soil water (= nFKWe + Vkap)	mm
E_{Haude}	= potentielle Evapotranspiration after HAUDE	mm/a

Problems with the „old“Renger-Wessolek regression equations:

- Not applicable in climate regions in Germany with rainfall > 800 mm/a

- Change of the evapotranspiration calculation method from the Haude-evapotranspiration to the FAO-grass reference-evapotranspiration ET_0

- Correction of rainfall values of the DWD after Richter (1995)

→ Further development necessary

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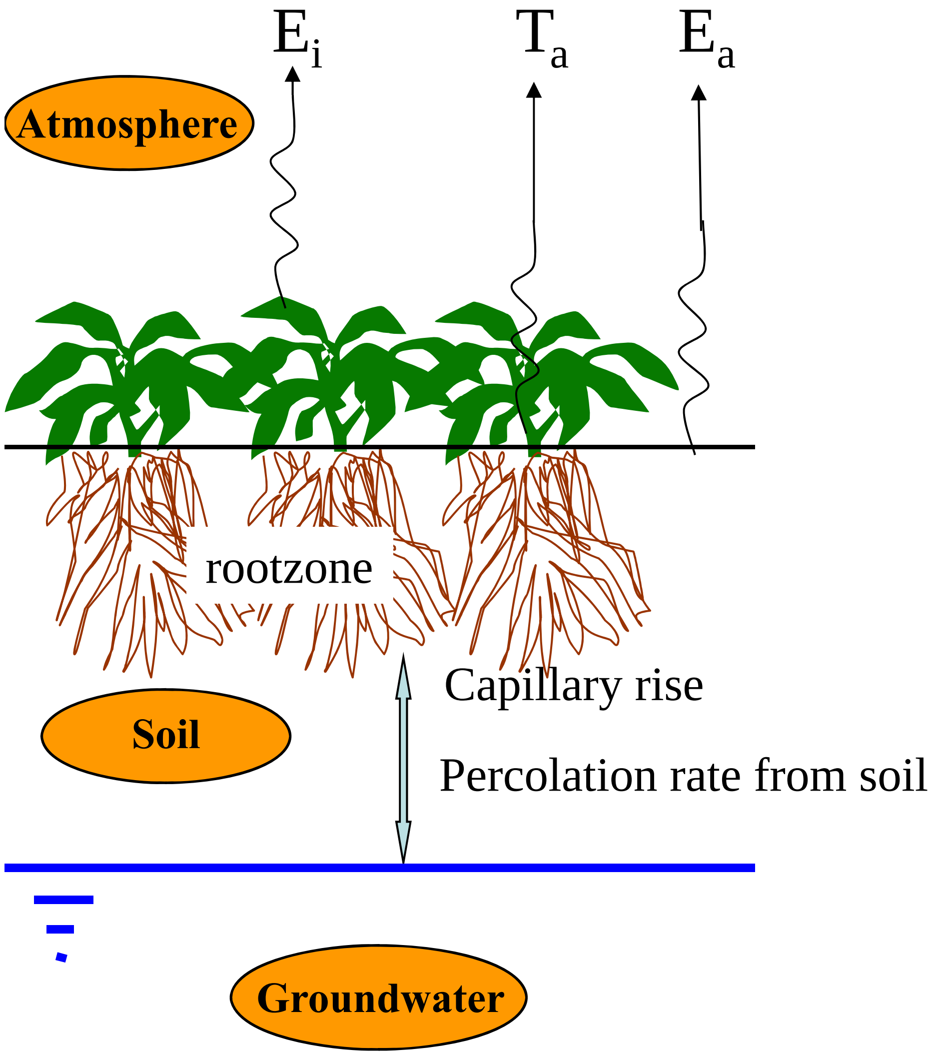
Procedure to develop new regression equations

- Simulation runs: percolation rate calculations for different land use, climatological areas, soils and groundwater depth in Germany
- Statistical evaluation of the simulation results and derivation of regression equations to calculate SWR from easily available soil and meterological data
- Validation of the regression equation results with independent data (catchment total outflow, lysimeter data)

Actual evapotranspiration EIT_a



Simulation model Soil Water Dynamics

Processes:

- Rainfall and infiltration
- Interception E_i
- Evaporation from the soil E_a
- Water uptake by plant roots (Transpiration = T_a)
- Capillary rise

Simulation on a daily basis

⇩ **Simulation**

- actual evapotranspiration EIT_a (= $E_i + E_a + T_a$)
- capillary rise Vkap(t)
- percolation rate SWR(t)

➡ **annual values**

Model scenarios

- 4 representative, well defined top soils combined with 4 sub soils (sandy, loamy sand, loam, loess soils)
- Different land use typs (cereals, root+tuber crops, grassland, coniferous forest, deciduous forest)
- 16 representative climatic areas in Germany (30 years daily meteorological data)
- One scenario without groundwater influence
- 5 scenarios with different groundwater level courses

= total simulations for 57.600 years on a daily basis

Longterm mean values of annual rainfall Nd_{Jahr} (summer Nd_{som} and winter rainfall Nd_{win}), annual FAO-grass-reference evapotranspiration $ET0_{Jahr}$ (summer $ET0_{som}$), climatic water balance in the summer half year KWB_{som} for the representative meteorological stations

Station	Nd_{som}	Nd_{win}	Nd_{Jahr}	$ET0_{Jahr}$	$ET0_{som}$	KWB_{som}
Freiburg	412	610	1022	680	528	-116
Würzburg	308	361	670	587	467	-159
Mannheim	310	428	738	619	495	-185
Stuttgart	272	460	732	598	469	-198
Coburg	387	440	827	509	419	-32
München-Riem	423	685	1109	571	454	-31
Kempten	576	838	1414	484	393	183
Bocholt	390	407	798	539	427	-37
Neumünster	435	455	890	499	411	24
Bremen	377	422	799	556	444	-67
Bad Hersfeld	379	418	797	501	410	-31
Teterow	265	345	610	542	441	-176
Magdeburg	240	314	555	555	447	-207
Uelzen	308	384	691	495	408	-100
Braunlage	770	618	1388	441	367	403
Chemnitz	351	371	722	539	427	-77

Concept

$$\frac{ET_a}{ET_0} = \text{Function (WV)}$$

$$WV = Nd_{som} + nFK_{we} + V_{kap} - 0.5 * R_0$$

ET_a = actual Evapotranspiration [mm]

ET_0 = potential FAO- Grass-reference evapotranspiration [mm]

WV = plant available amount of water in the summer half year [mm]

Ndsom = rainfall in the summer half year [mm]

nFKwe = plant available field capacity in the effective rooting zone [mm]

Vkap = capillary rise from groundwater into the rooting zone [mm]

R_0 = surface runoff [mm]

Percolation rate $SWR = Nd_{Jahr} - ET_a - R_0$ mm/a

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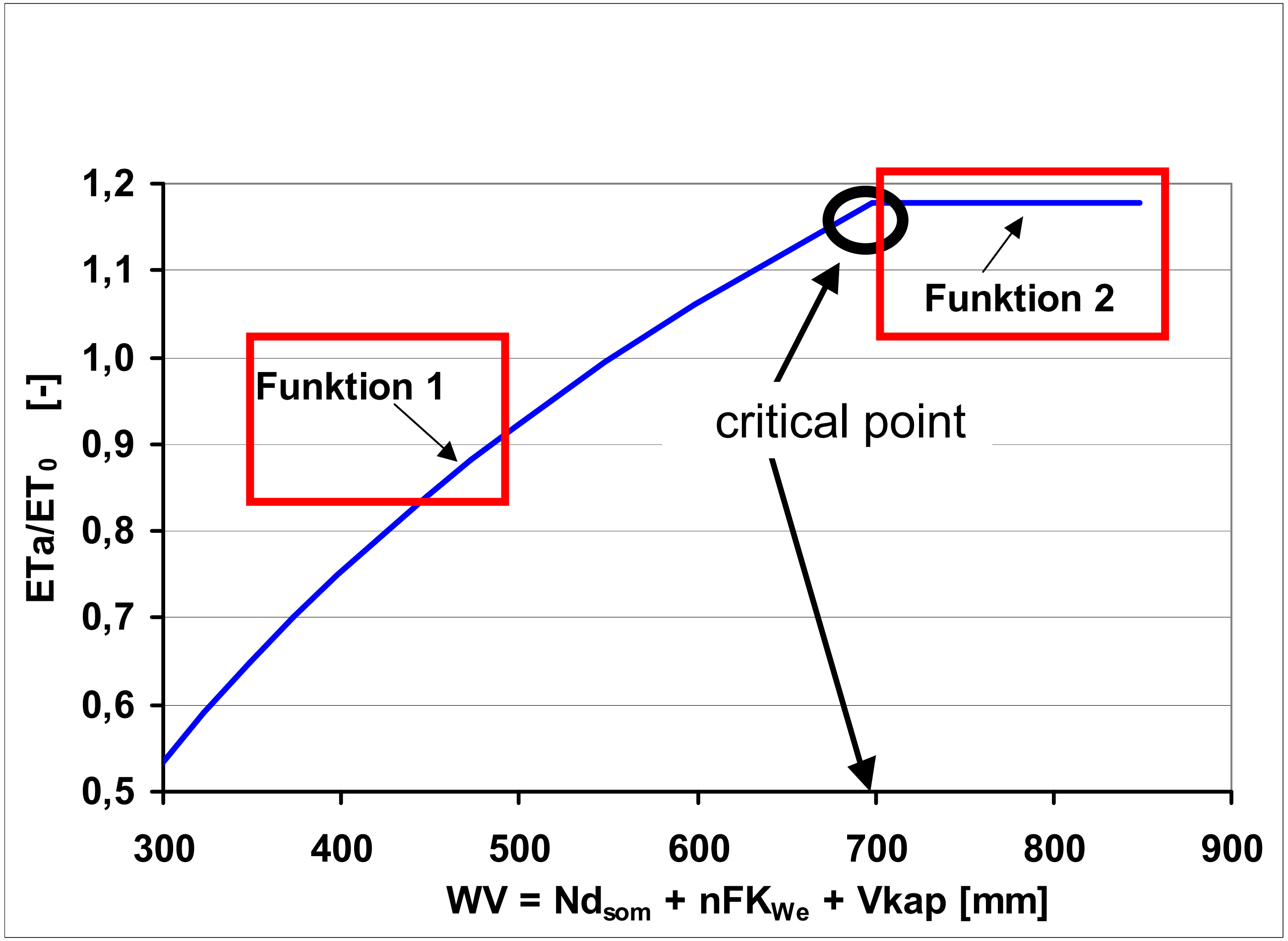
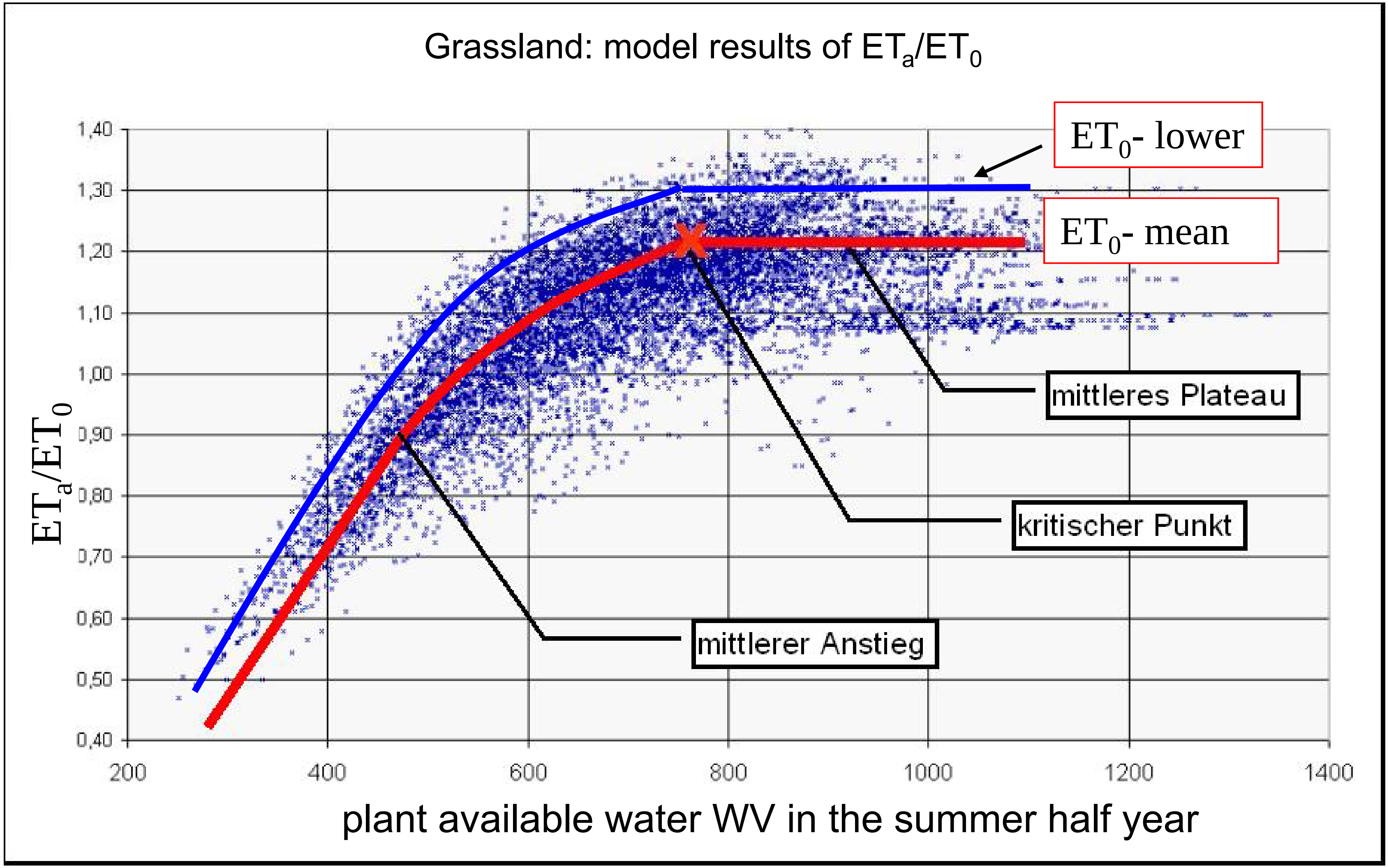
Concept for a new method

Quotient ET_a/ET_0



plant available water WV in the summer half year

Derivation of regression equations for Grassland



land use specific regression analysis

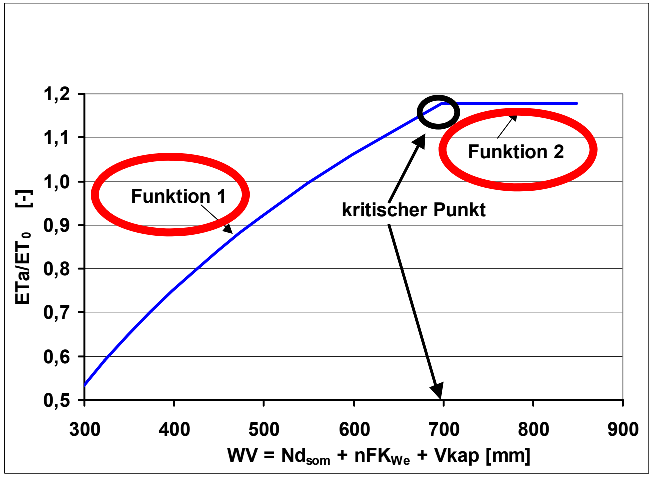
WV = plant available water in the summer half year [mm]

- WV ≤ P_{krit}

$$ET_a = \text{function}(WV, ET_0)$$

- WV > P_{krit}

$$ET_a = \text{function}(ET_0)$$



plant available water WV in the summer half year

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Regression equations for Grassland für Grünland

plant available water WV in the summer half year: WV= $nFK_{We} + Nd_{som} + v_{kap}$

- $WV \leq 700$ mm :

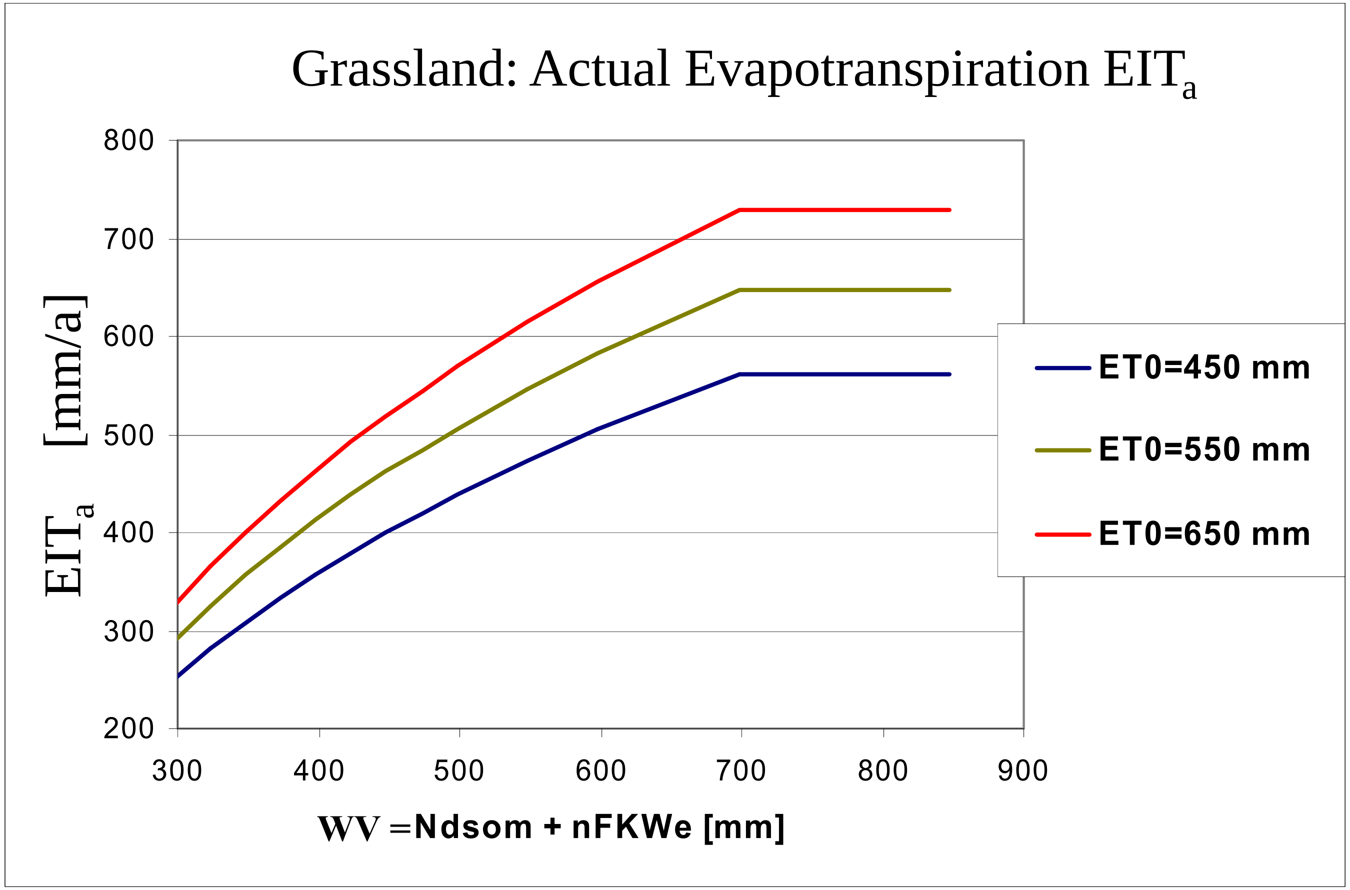
$$SWR = Nd_{jahr} – ET0*[1.79*\log(WV) -3.89]* [0.53*\log(1/ET0) + 2.43]$$

- $WV > 700$ mm :

$$SWR = Nd_{jahr} – 1.2*ET0 [0.53*\log(1/ET0) + 2.43]\}$$

SWR = annual percolation rate (Nd_{Jahr} - ET_a) mm/a

Absolute dependence of the actual Evapotranspiration EIT_a from water availability WV and potential FAO-Evapotranspiration ET_0



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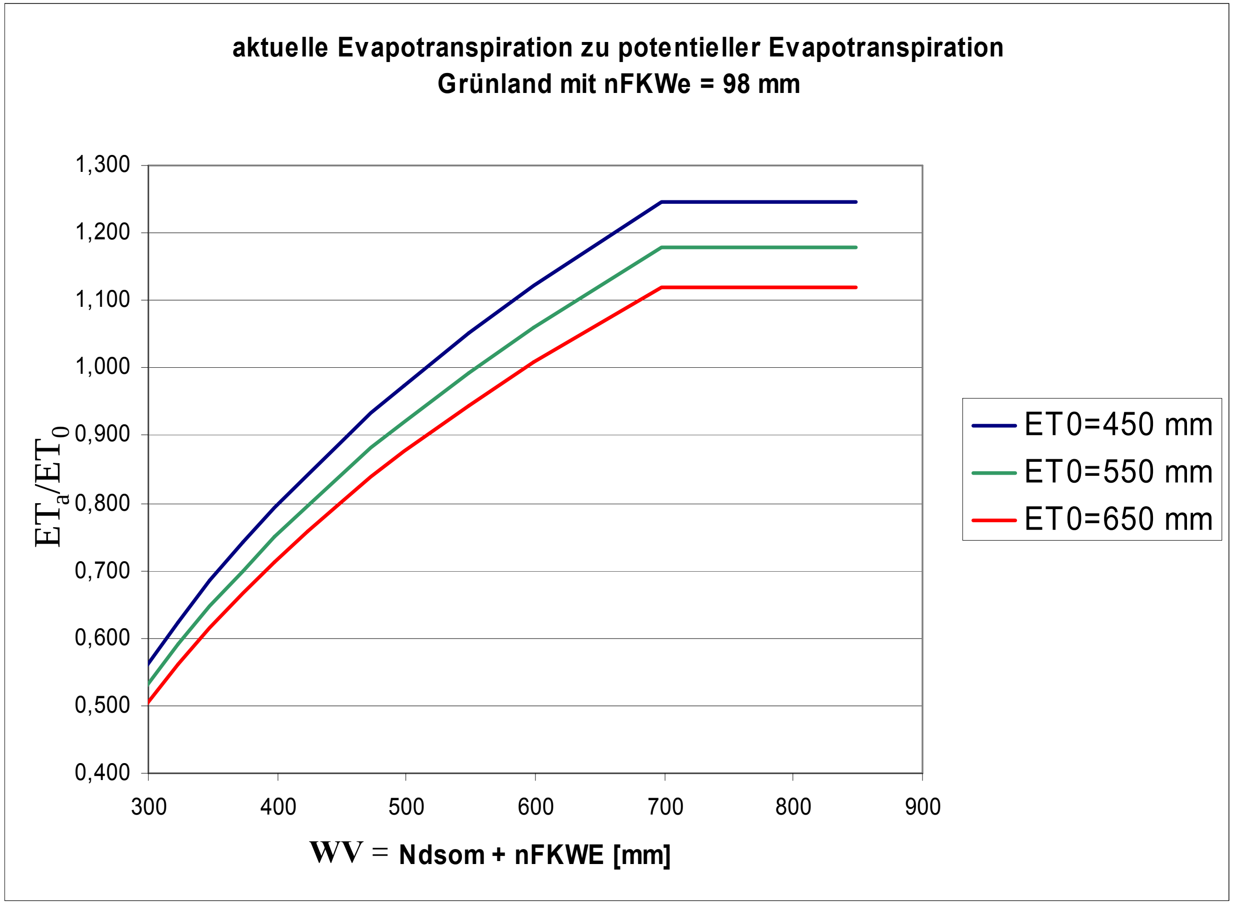
relative dependence of the actual Evapotranspiration EIT_a from water availability WV and potential FAO-Evapotranspiration ET_0



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Regression equations for arable land

Mean values from winter wheat, winter barley and sugar beets

Critical point of water availability WV = 700 mm

- *WV ≤ 700 mm* :

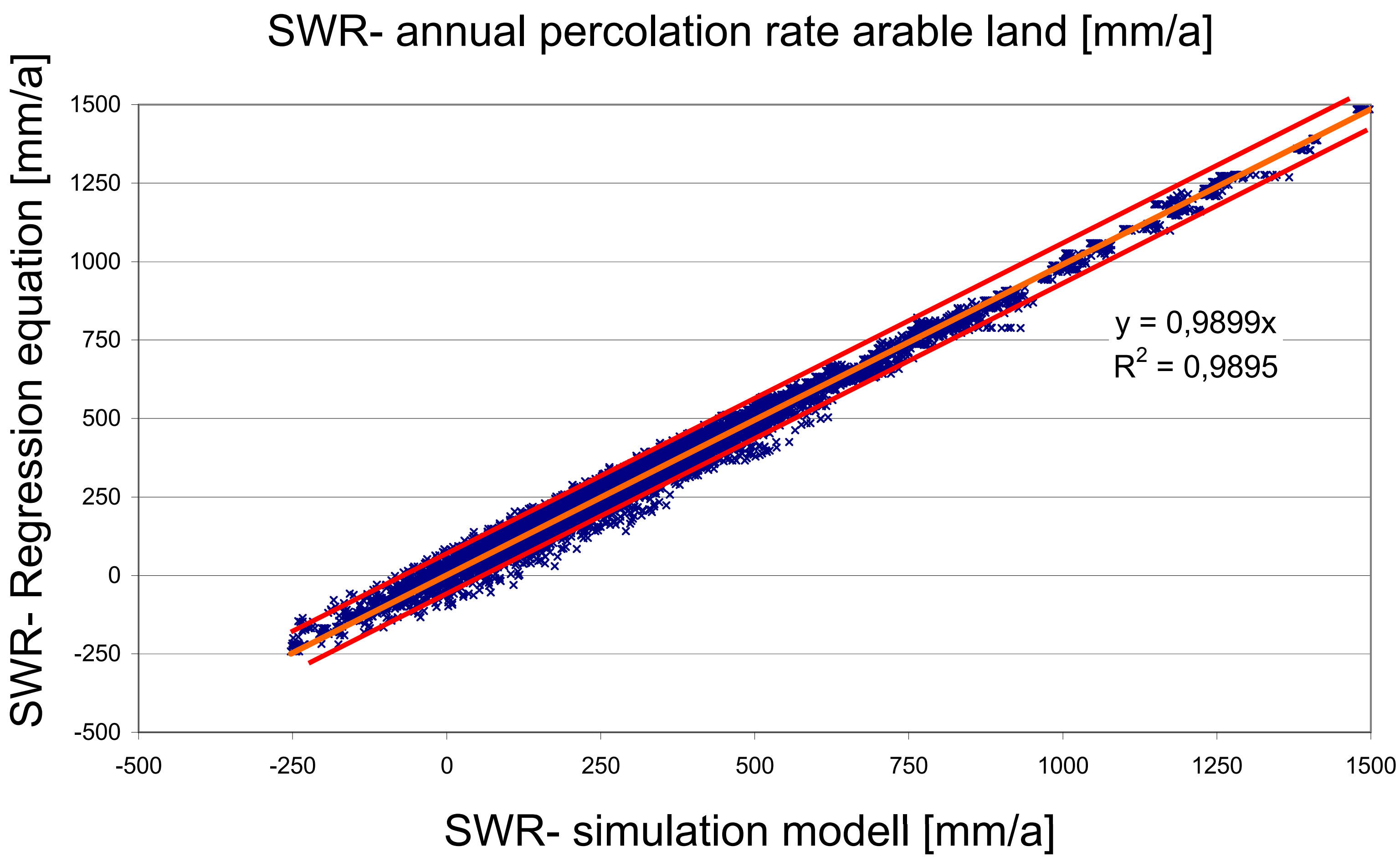
$$SWR = Nd_{jahr} – ET0*[1.45*log(nFK_{We} + Nd_{som} + v_{kap}) -3.08]* [0.685*log(1/ET0) + 2.865]$$

- *WV > 700 mm* :

$$SWR = Nd_{jahr} – 1.05*ET0* [0.685*log(1/ET0) + 2.865]\}$$

➔ **Regression equations also for coniferous and deciduous forests**

Comparison of the annual percolation rate SWR for arable land as calculated with the regression equation and with the simulation model



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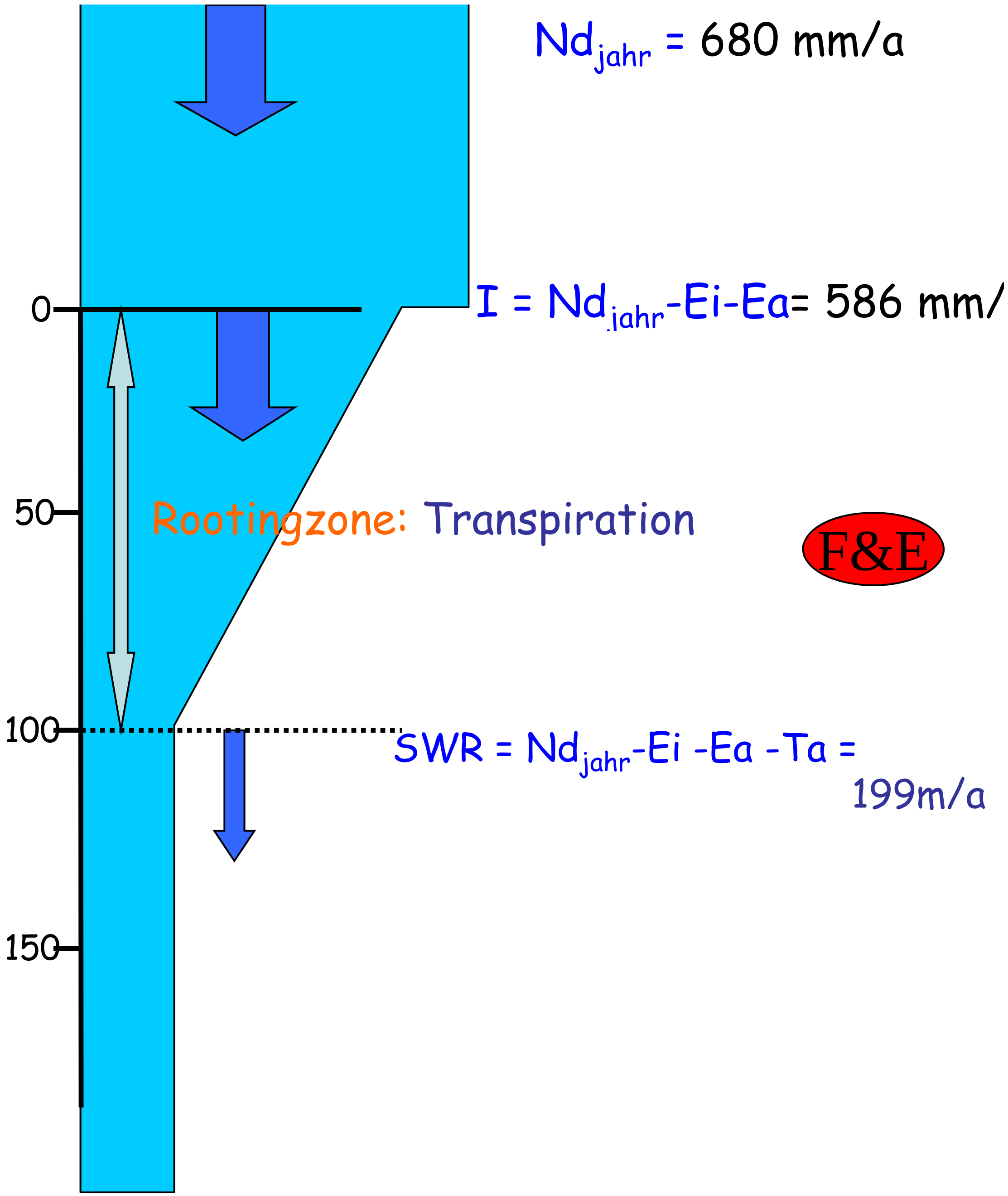
Example percolation rate SWR of grassland:

Nd_{som} = 330 mm
Nd_{win} = 350 mm
ET_0 = 558 mm/a
nFKWe = 135 mm

SWR = 199 mm/a

SWR = annual percolation rate from the soil [mm/a]



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Regionalisation of the percolation rate from the soil in Germany

Data basis:

Soil	BÜK 1000: soil map of Germany 1: 1.000.000, 72 legend units with land use specific soil reference profiles of the main soils in the legend → nFKWe und WV for arable land, grassland and forest soils
Land use	CORINE-Landcover: land use combined in classes Map overlay with the BÜK 1000
Relief	Digital elevation model: Rasterdata ca. 30 m → Derivation of geometric relief parameter, distribution of slope gradients , basis for calculation of surface runoff
Climate	Rainfall: the mean annual rainfall from 1961-1990 as raster data In a resolution of 1 km^2 (not-corrected and corrected after Richter, 1995) Evapotranspiration: mean annual potential evapotranspiration ET_0 as Grass-Reference evapotranspiration (FAO)

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- Insert maps:
- BÜK 1000
- Corine
- Rainfall
- FAO

The TUB-BGR-Method

Derivation of reference profiles for the main soils in a legend unit :

- spatial differentiation: ⇨ regional specific reference profiles
- land use specific differentiation: ⇨ nutzungsspezifische Referenzprofile

Example: Legend unit 31 of the BÜK 1000: BB-PP and PP-BB of nutrinet poor sandy soils

arable land 50 %
Podsol-Braunerde

nFKWe = 80 mm

coniferous forest 45 %
Podsol-Braunerde

nFKWe = 110 mm

grassland 5%
anmooriger Gley

nFKWe = 130 mm
hohe Vkap

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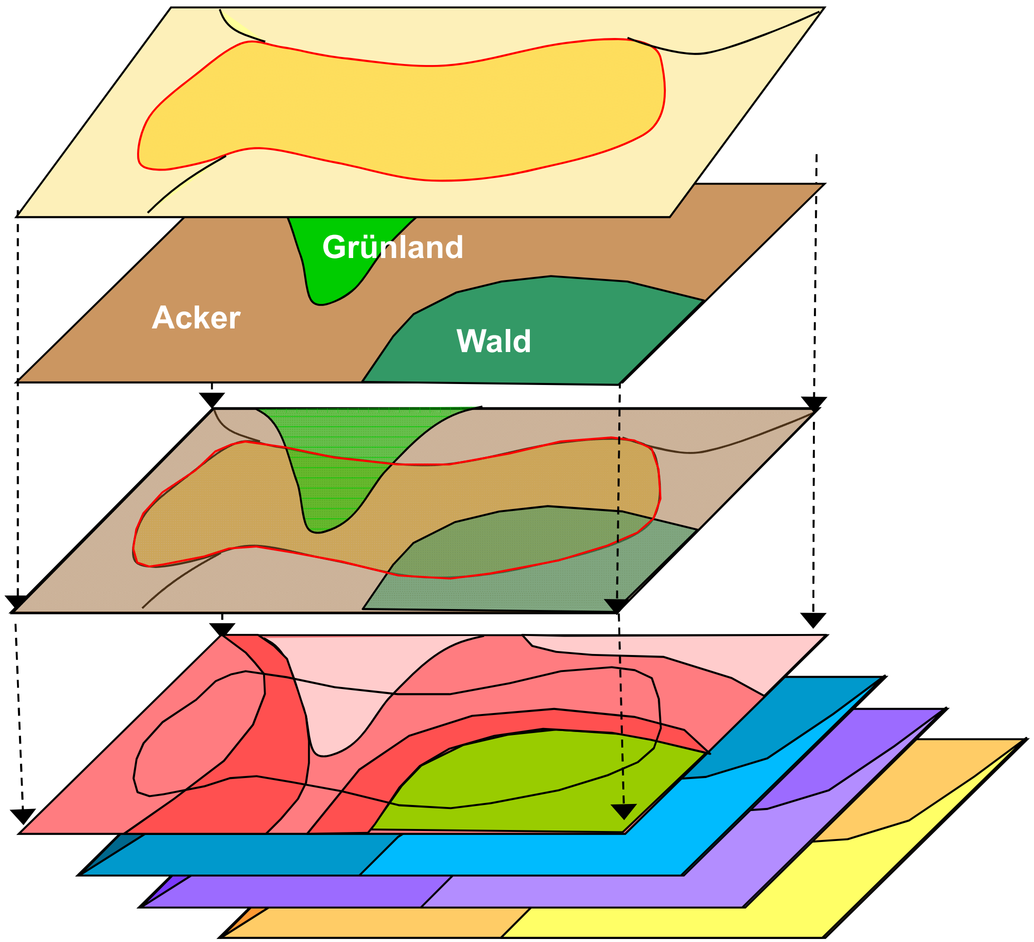
Workflow, Information Layer

- soil data : BÜK 1000
- land use data: CORINE LC
- map overlay soil - land use
- surface runoff
- Summer rainfall
- winter rainfall
- FAO-Grass-Reference-Evapotranspiration



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Workflow, Information Layer

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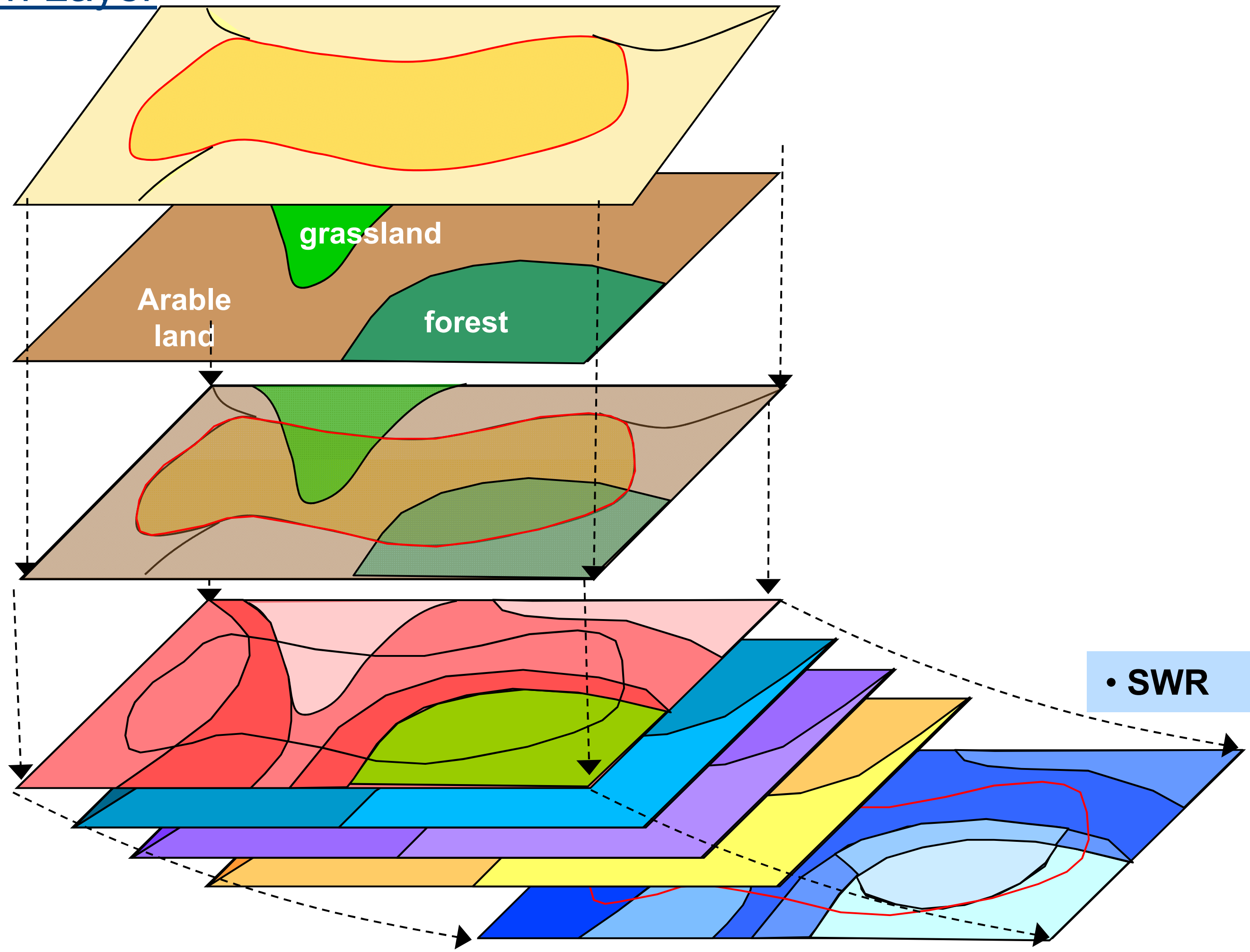

Annual percolation rate

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CORINE land cover legend:

ARTIFICIAL SURFACES

URBAN FABRIC
- 111 Continuous urban fabric
- 112 Discontinuous urban fabric

INDUSTRIAL, COMMERCIAL AND TRANSPORT UNITS
- 121 Industrial, commercial and public units
- 122 Road and rail networks and associated land
- 123 Port areas
- 124 Airport

MINES, DUMPS AND CONSTRUCTION SITES
- 131 Mineral extraction sites
- 132 Dump sites
- 133 Construction sites

ARTIFICIAL NON-AGRICULTURAL VEGETATED AREAS
- 141 Green urban areas
- 142 Sport and leisure facilities

AGRICULTURAL AREAS

ARABLE LAND
- 211 Non-irrigated arable land

PERMANENT CROPS
- 221 Vineyards
- 222 Fruit trees and berries plantations

PASTURES
- 231 Pastures

HETEROGENEOUS AGRICULTURAL AREAS
- 242 Complex cultivation patterns
- 243 Land principally occupied by agriculture, with significant areas of natural vegetation

FOREST AND SEMINATURAL AREA

FORESTS
- 311 Broad-leaved forest
- 312 Coniferous forest
- 313 Mixed forest

SCRUBS AND/OR HERBACEOUS VEGETATION
- 321 Natural grassland
- 322 Moors and heathland
- 324 Transitional woodland-scrub

OPEN SPACES WITH LITTLE OR NO VEGETATION
- 331 Beaches, dunes, sand
- 332 Bare rock
- 333 Sparsely vegetated areas
- 334 Burnt areas
- 335 Glaciers and perpetual snow

WETLANDS

INLAND WETLANDS
- 411 Inland marshes
- 412 Peat bogs

COASTAL WETLANDS
- 421 Salt marshes
- 423 Intertidal flats

WATER BODIES

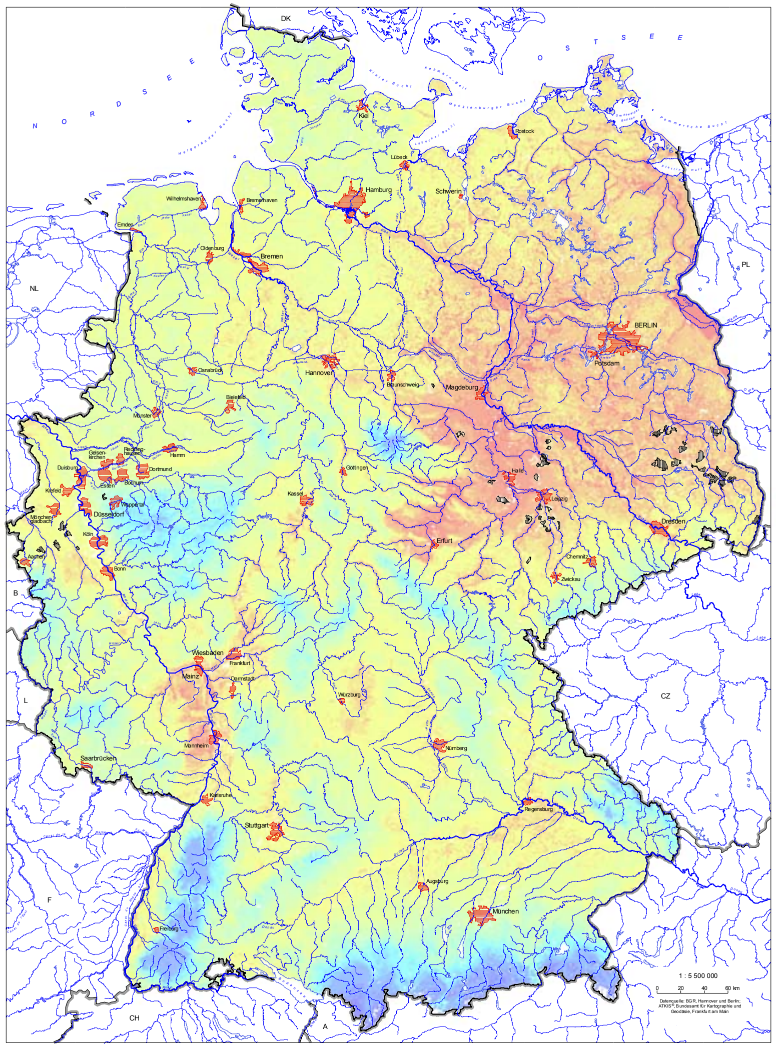
INLAND WATERS
- 511 Water courses
- 512 Water bodies

MARINE WATERS
- 521 Coastal lagoons
- 522 Estuaries
- 523 Sea and ocean

Assignment of the CLC-keys to the 4 main land use types to determine SWR

CLC - key	description	Arable land	grassland	Deciduous forest	Coniferous forest
112	Discontinuous urban fabric	25 %	50 %	25 %	0 %
141	Green urban areas	0 %	60 %	40 %	0 %
211	Non irrigated arable land	100 %	0 %	0 %	0 %
221	vineyards	0 %	30 %	70 %	0 %
222	Fruit trees and berries plantations	0 %	30 %	70 %	0 %
231	pastures	0 %	100 %	0 %	0 %
243	Land principally occupied by agri-culture with significant areas of natural vegetation	35 %	40 %	25 %	0 %
311	Broad leaved forest	0 %	0 %	100 %	0 %
312	Coniferous forest	0 %	0 %	0 %	100 %
313	Mixed forest	0 %	0 %	50 %	50 %
321	Natural Grassland	0 %	100 %	0 %	0 %
322	Moors and heathland	0 %	70 %	30 %	0 %
324	Transitional woodland shrubs	0 %	70 %	30 %	0 %
411	Inland marshes	0 %	75 %	25 %	0 %

Annual percolation rate SWR from soil in Germany (HAD)



Mittlere Sickerwasserrate aus dem Boden in mm/Jahr

0
50
100
150
200
300
400
500
600
700
800
900
1000
1500
2000

nicht bewertete Flächen

Versiegelte Flächen in größeren Städten

Technogen gestaltete Böden, große Abbauflächen und Halden

HYDROLOGISCHER ATLAS VON DEUTSCHLAND
Herausgegeben vom Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

4.5 Sickerwasserrate aus dem Boden

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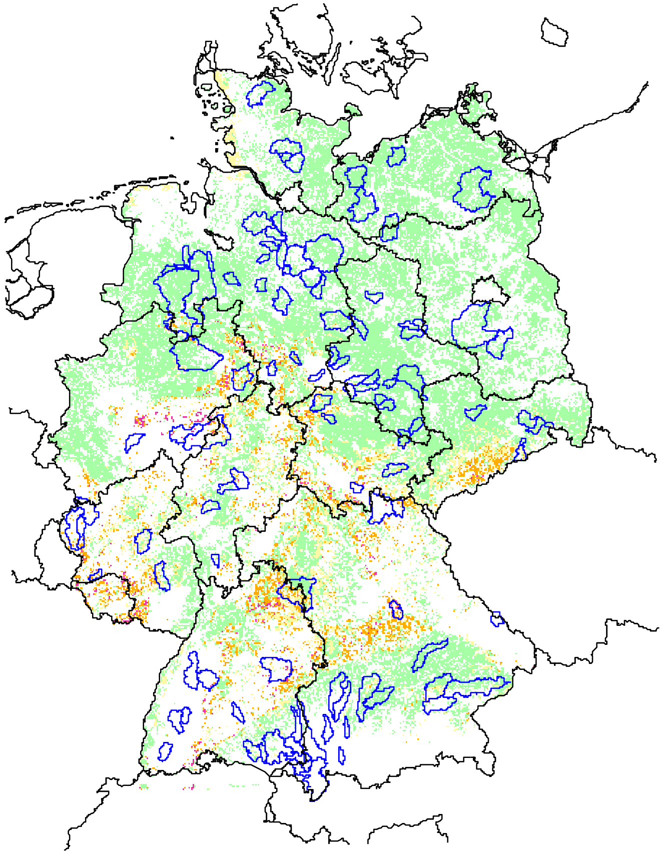
Validation of the regression equations



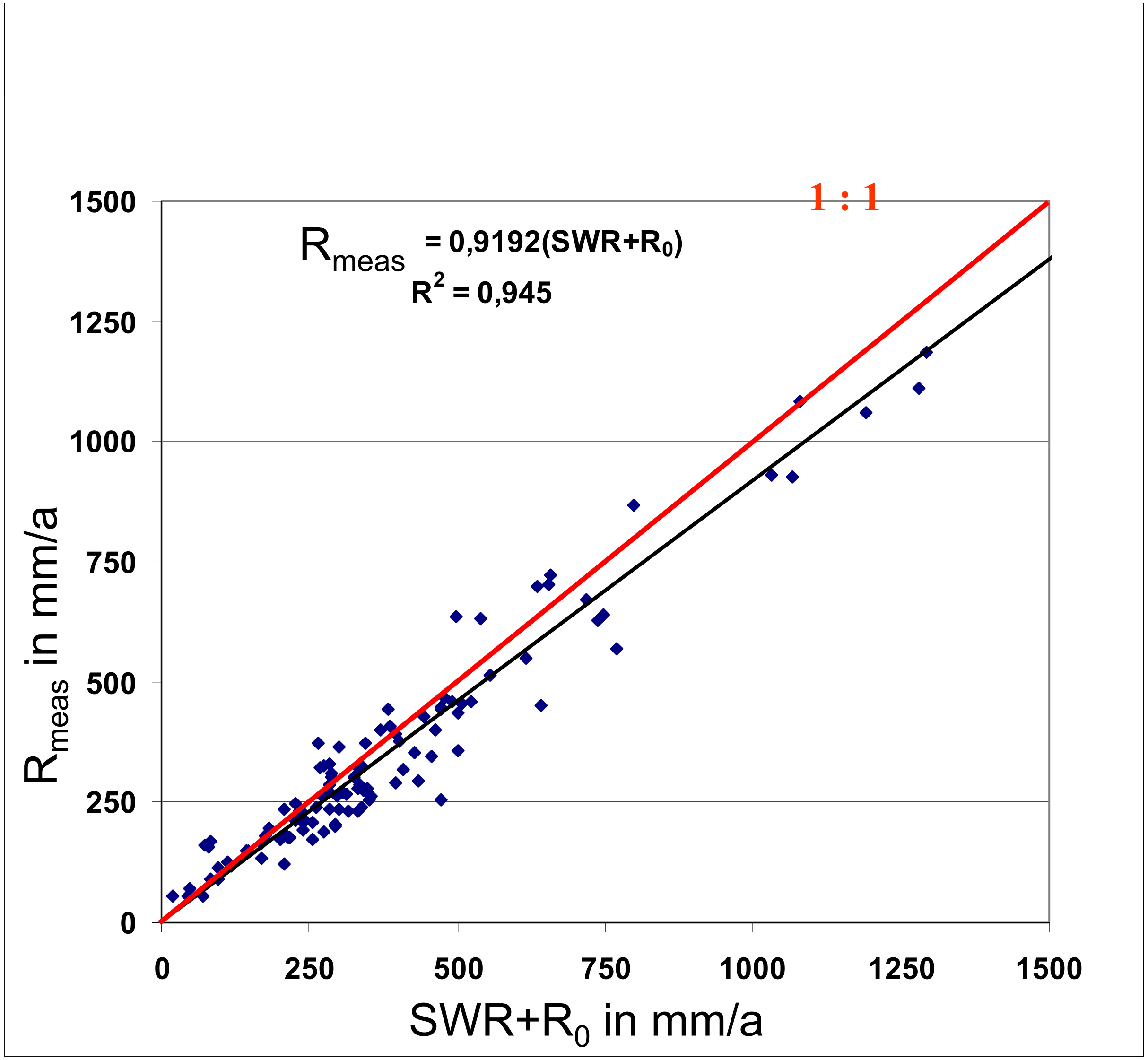
Surface runoff from arable land

- 0 - 25 mm/a
- 25 – 50 mm/a
- > 50 mm/a
- Not evaluated

Position of the 106 catchment areas with total runoff measurements

Catchment areas

Measured and calculated Total Runoff R of 106 catchment areas



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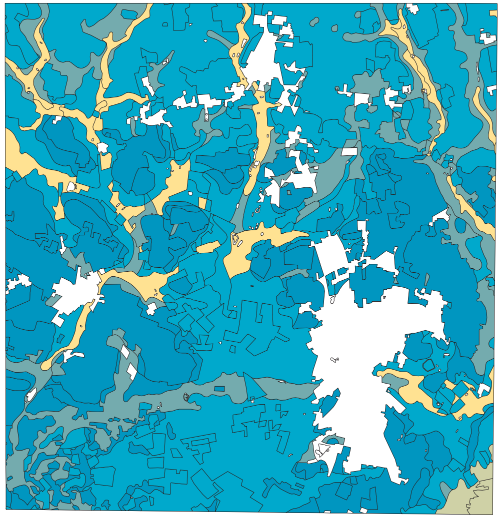
Conclusions for further developments of the TUB-BGR- method

- The TUB-BGR-method gives good results, but the systematic overestimation of the total runoff must be studied further
- Regionalisation of the regression equations must be considered
- The method should be tested and validated for other catchment areas in Germany
- Especially groundwater influenced sites and catchment areas with organic soils (peat) and clay soils should be investigated
- An improved method to determine capillarry rise depending on climate and soil conditions should be developed

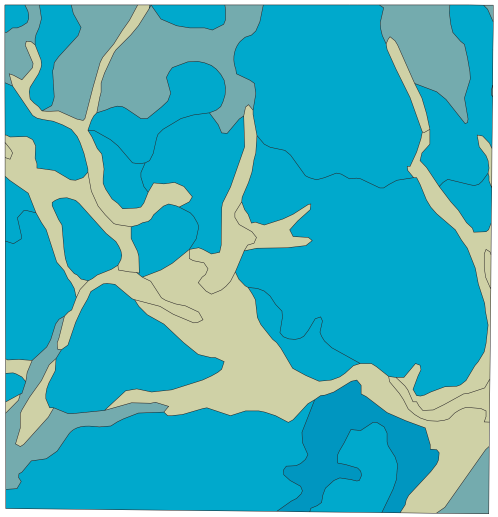
Presentation of the annual percolation rate SWR at different scales on the basis of soil maps from the area ‚Vechta‘
(BK25: 1:25.000; BSK200: 1:200.000; BÜK1000: 1:1.000.000)

BK 25

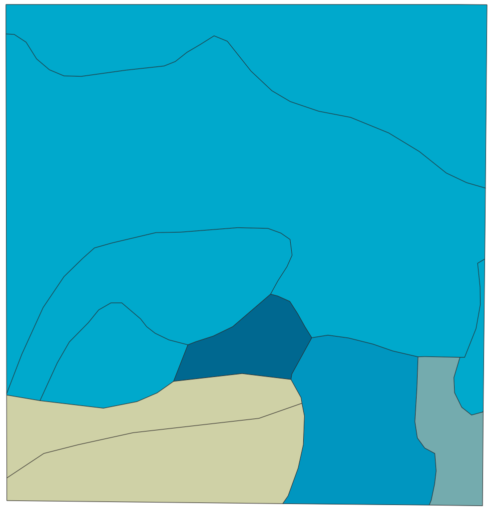


- < 50 mm
- 50 - 100 mm
- 100 - 150 mm
- 150 - 200 mm
- 200 - 250 mm
- 250 - 300 mm
- > 300 mm

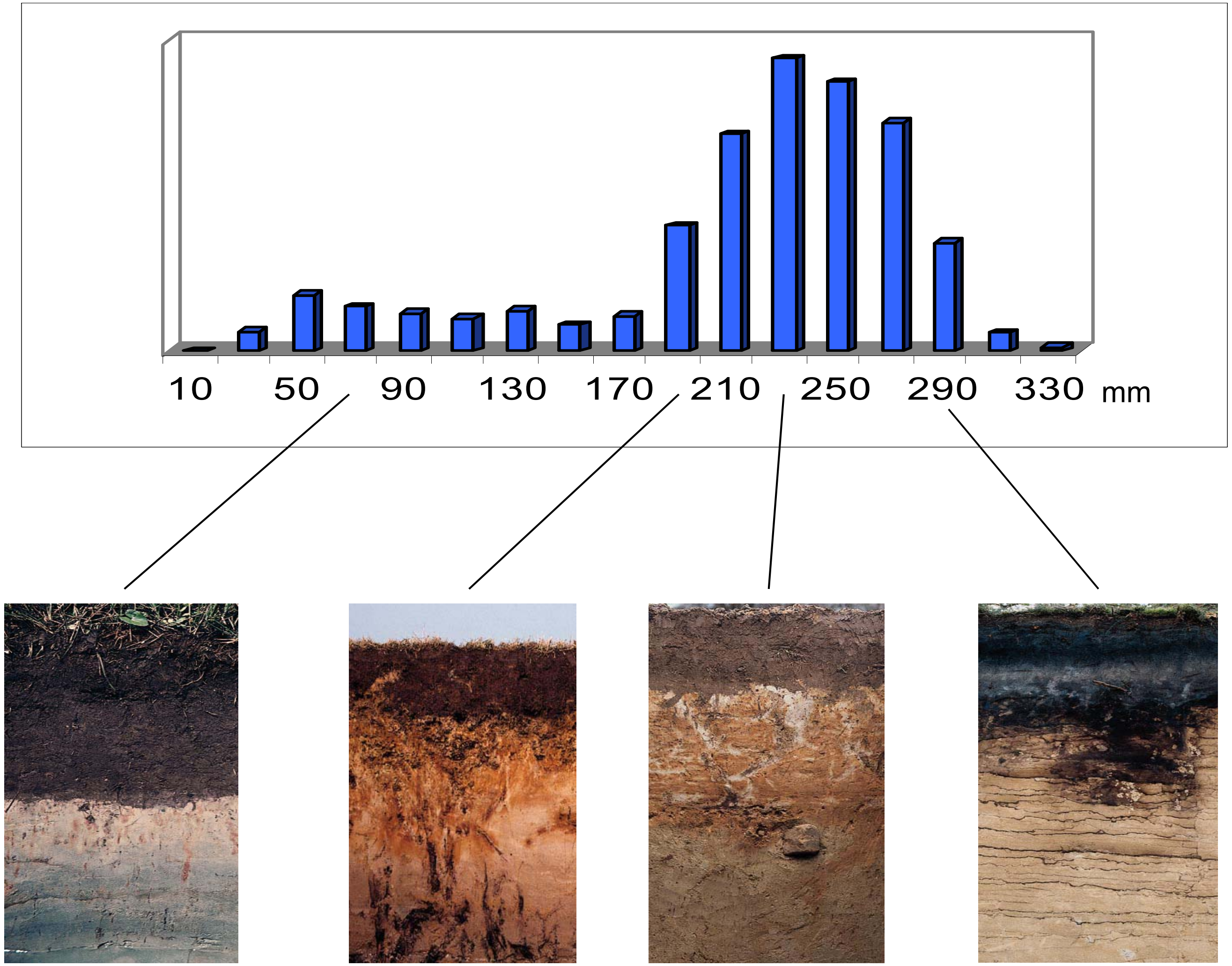
BSK 200



BÜK 1000

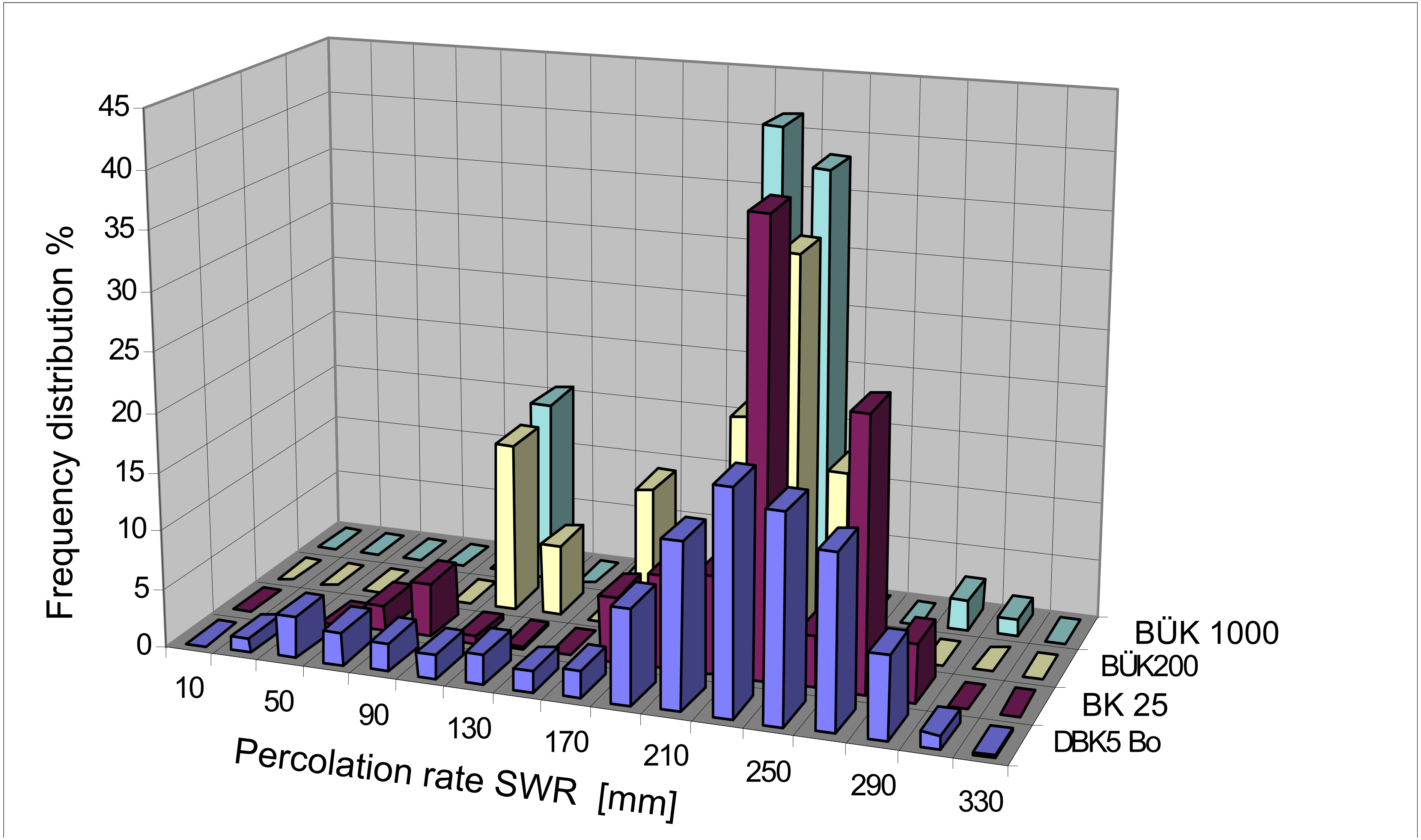


The TUB-BGR-Method



Frequency distribution of the mean yearly percolation water rate

on sheet ‚Vechta‘ after field mapping results; scale 1 : 5.000



Frequency distribution of the mean annual percolation rate SWR of the TK25 map ‚Vechta' as calculated on soil maps of different scales

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