Modelling impact of wetland's management on its water regime

Dept. of Land and Water Resources Management
Slovak University of Technology
in Bratislava


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Motivation

- within the framework of the GEF project „Conservation, Restoration and Wise Use of Rich Fens in the Slovak Republic"

- DAPHNE – Institute of Applied Ecology

- Analysis of hydrological regime of wetlands

- To identify reasons of wetlands degradation:
  - Changes in hydrological regime
  - Human activities (drainage systems)
  - **Changes in management of wetlands**

- Proposal of measures to improve hydrological regime

Outline

- Aims
- Simulation of soil water regime of wetlands
- Case studies:
  - Kláštorské lúky wetland
  - Abrod wetland
  - Belianske lúky wetland
- Results
- Recommendations

Aims

- To evaluate the impact of wetland management on:
    - ✓ Soil water regime
    - ✓ Seasonal distribution of evapotranspiration and its components

- Methodology: mathematical modelling of soil water regime

- Application of proposed methods to three wetlands with different management practicies
-
    - ✓ Kláštorské lúky
    - ✓ Abrod
    - ✓ Belianske lúky

Simulation of soil water regime

- daily time step

- HYDRUS-ET: 1D model describing transport of water and solutes in the soil – plant - atmosphere system

- Developed at U.S.Salinity Laboratory, Department of Agriculture, Agricultural Research Service Riverside, CA, U.S.A.

- Part for simulation of evapotranspiration and its components (evaporation, transpiration) was developed at IH SAS

Richards equation

• describing water flow in soil with root extraction, eventually layered soil profile

$$\frac{\partial h_w}{\partial t} = \frac{1}{c(h_w)} \frac{\partial}{\partial z}\left[k(h_w)\left(\frac{\partial h_w}{\partial z} + 1\right)\right] - \frac{S(z,t)}{c(h_w)}$$

h_w - soil water potential cm

z - vertical coordination [cm]

$k(h_w)$ - unsaturated soil hydraulic conductivity[cm.d^{-1}]

$S(z,t)$ - roots extraction rate [cm.d^{-1}]

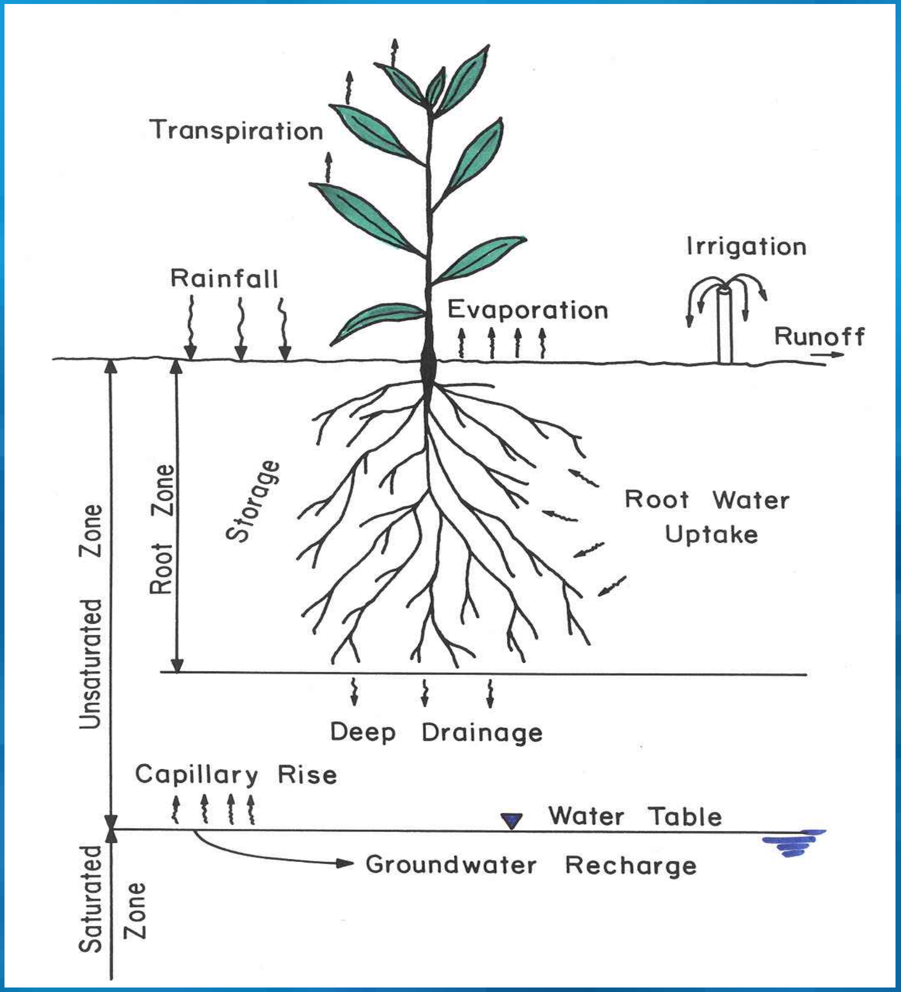
θ - volumetric soil water content [cm^{3}. cm^{-3}]

$$c(h_w) = \frac{\delta\ \theta}{\delta h_w}$$

- specific water capacity

Input data

- soil characteristics
- meteorological data
- canopy (plant) characteristics
- initial and boundary conditions

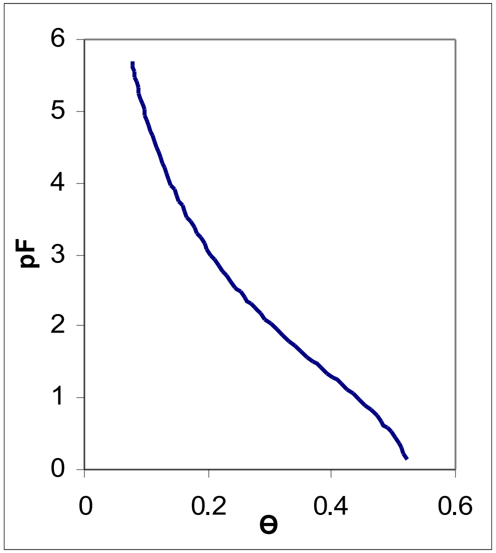


Soil hydrophysical characteristics

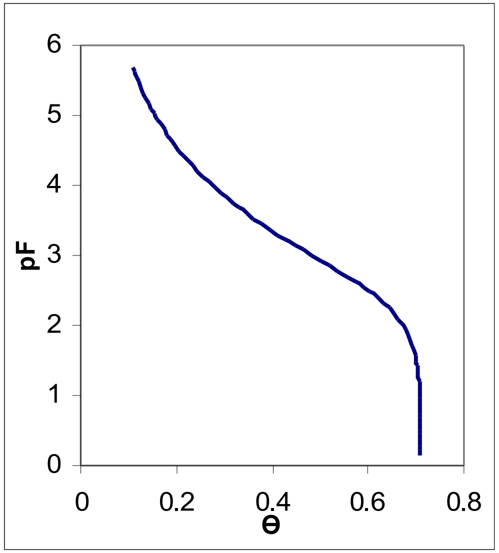
Soil layer 0-100 cm

✓ Relationships between soil water potential and soil water content (SWRC) were estimated in laboratory using soil samples in pressure chambers, then approximated using van Genuchten method

✓ Saturated hydraulic conductivity K was measured in laboratory



Kláštorské lúky



Abrod

Meteorological data

Daily values – precipitation, air temperature, wind velocity, sunshine duration, water vapour pressure – measured by SHMI

Plant characteristics

Leaf area index LAI - measured,
Roughness and albedo of evaporation surface (literature data),
Rooting depth – literature + evaluation

Initial and boundary conditions

distribution of water content θ in soil profile (measured)

- **upper** → meteorological characteristics
- **bottom** → ground water level (measured), free drainage

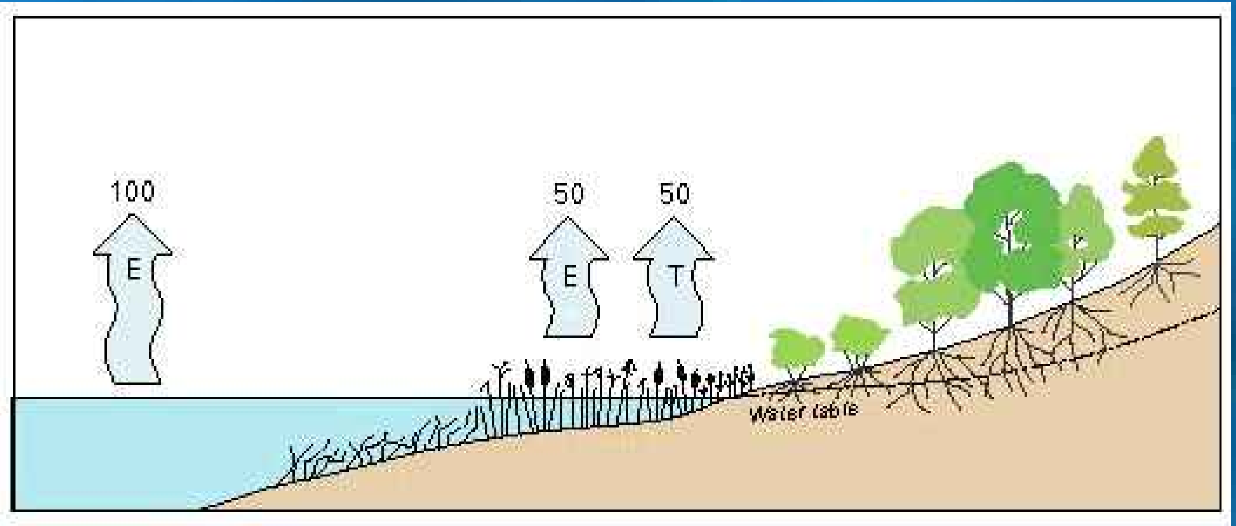
Evapotranspiration evaluation

✓ modified Penman - Monteith method (Penman, 1948 Monteith, 1965)

✓ Modification of aerodynamic resistances based on results of Budagovskij (1964) and Obukhov, Monin (1971)

✓Evapotranspiration structure depends on LAI

✓Verified for Slovakia by Novák (1989)



Case studies

- **Three wetlands**
  - ✓ Kláštorské lúky
  - ✓ Abrod
  - ✓ Belianske lúky

- **Comparison of simulation results for**
  - ✓ different canopies
  - ✓ different management methods (non-managed, mown grass)

Kláštorské lúky wetland (different canopies)

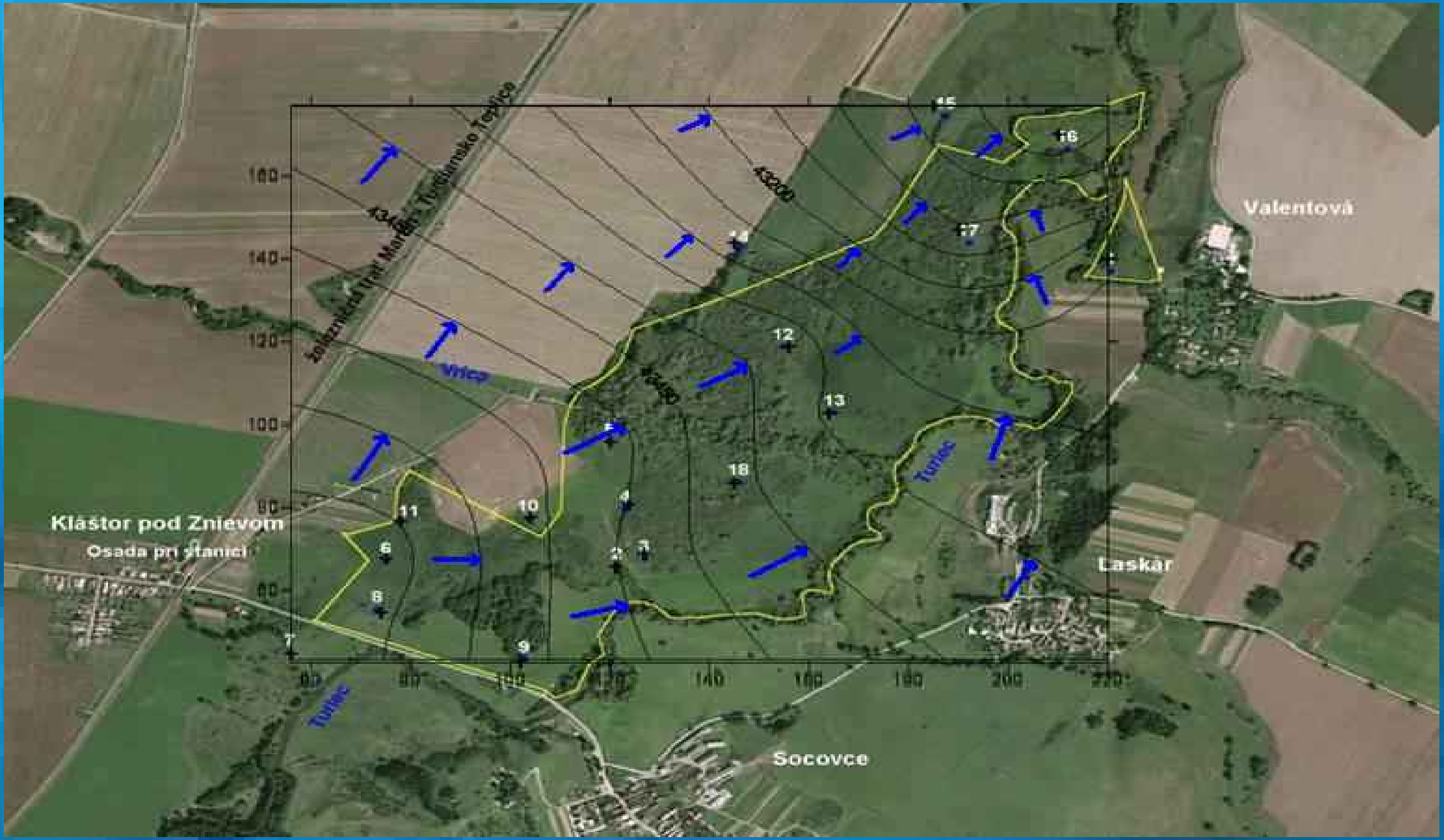
- ✓ Management of the wetland
  - ✓ grass is not mown regulary
  - ✓ rare grass canopies are overgrown by invaded reed

- ✓ Changes in soil water regime were evaluated for two different canopies: **grass, reed**

Kláštorské lúky

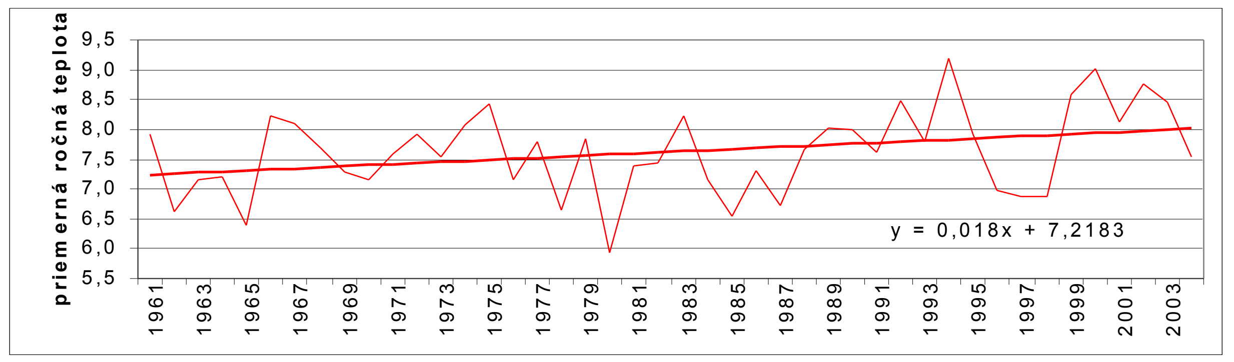
Kláštorské lúky

Kláštorské lúky
ground water level isolines



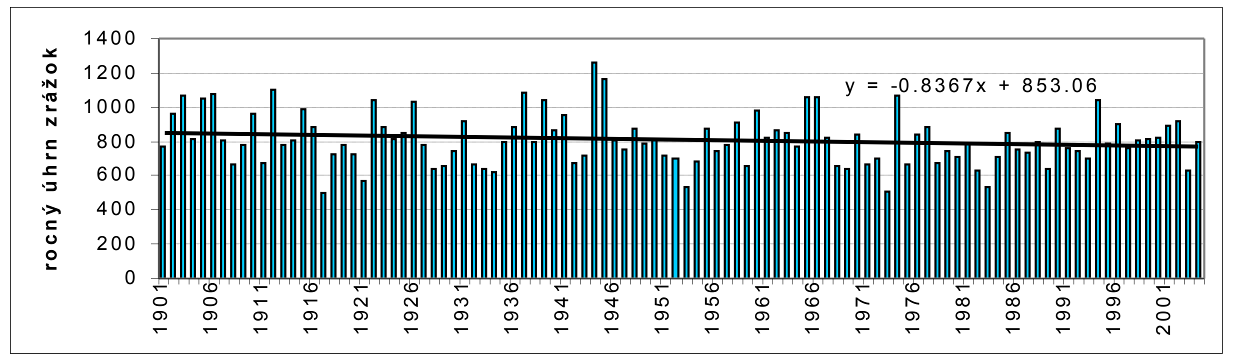
Basic input data

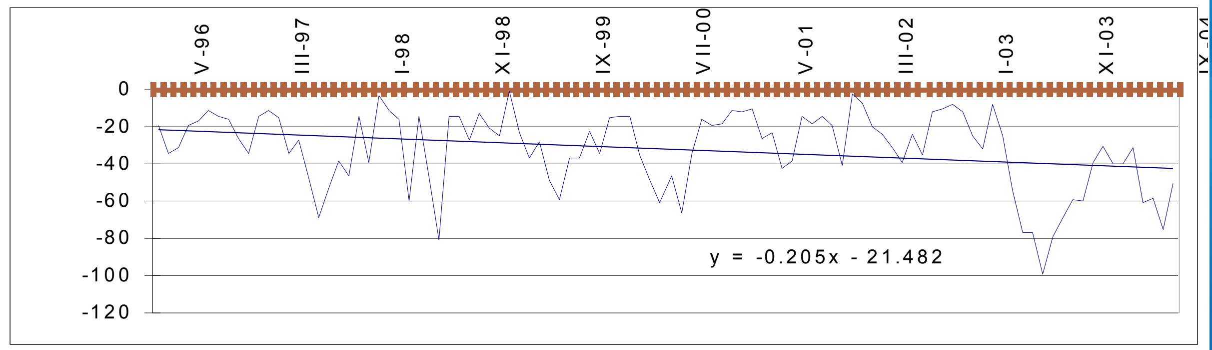
MS Kláštor pod Znievom



Air temperature
annual averages

Precipitation
annual totals





GW level well N. **6**
weekly averages

Kláštorské lúky

Leaf area index LAI

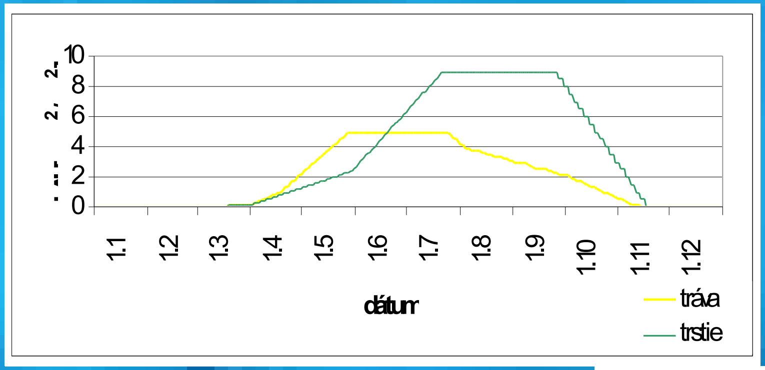
Measurement in the field (July, 22.)

canopy	LAI [m^2/m^2]
Grass	2.22
Galium aparine agg. (Lipkavec obyčajný)	0.22
Reed (Phragmites australis, trsť obyčajná)	5.02
Cirsium rivulare (Pichliač močiarny)	1.20
Δ other green parts	0.40
Total	**9.07**

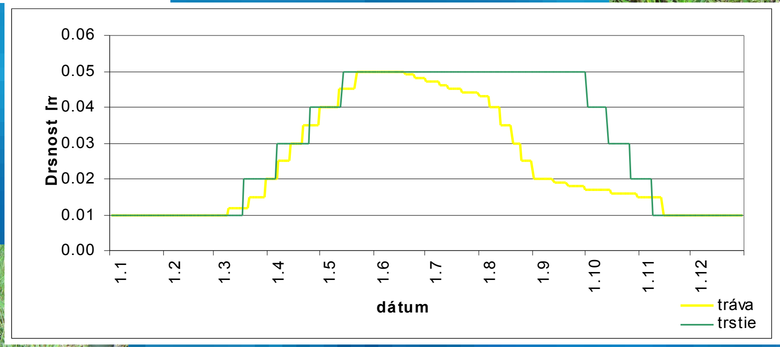
Kláštorské lúky

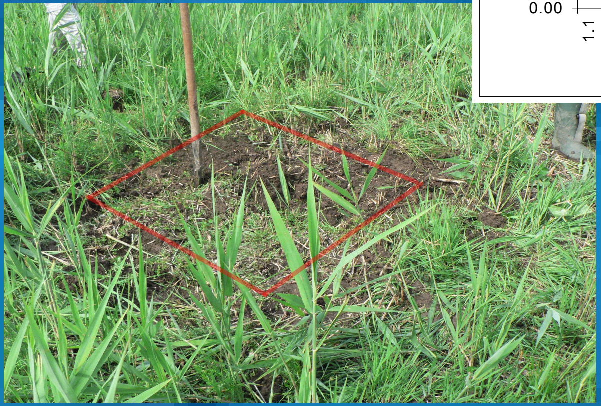
Canopy characteristics

LAI

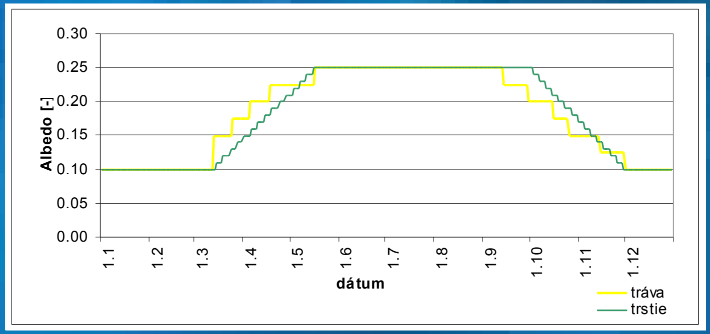


Roughness





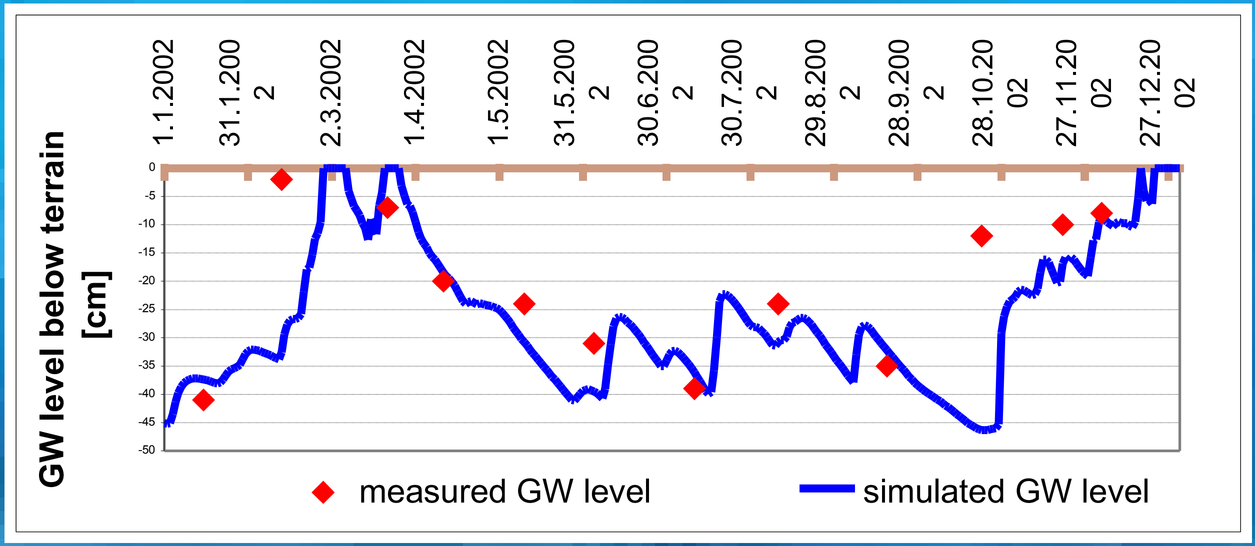
Albedo



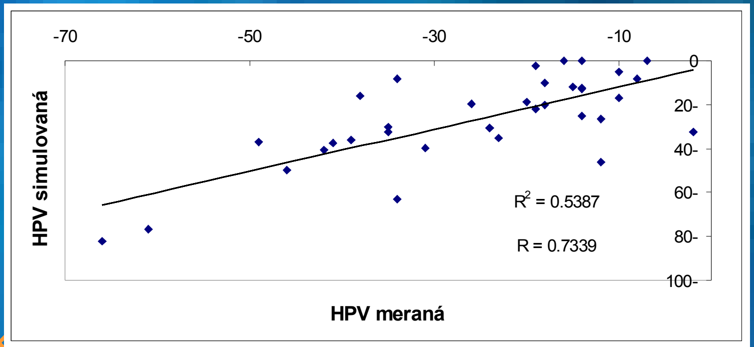
Kláštorské lúky

Soil water regime simulation

- ✓ Measured and simulated ground water level (HYDRUS-ET)
- ✓ Model verification



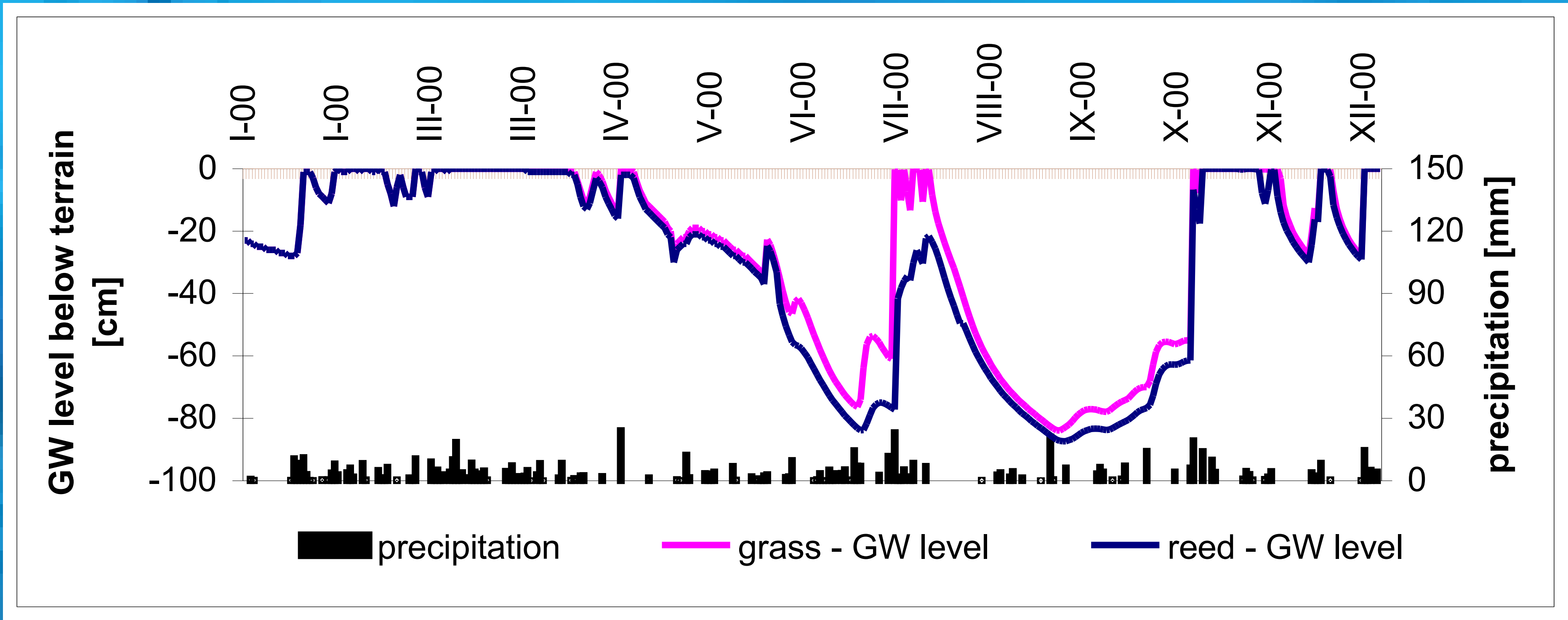
- ✓ regression
- ✓ correlation coefficient r = 0.74



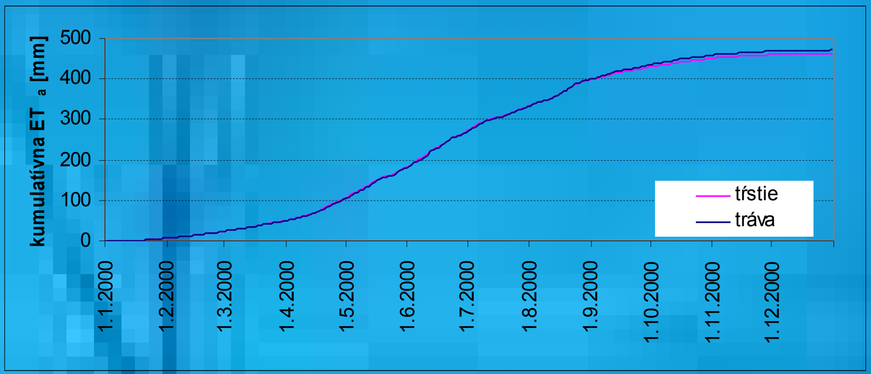
Kláštorské lúky

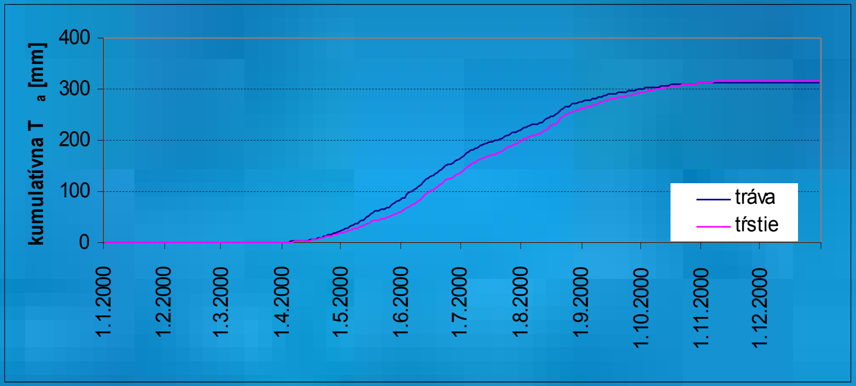
GW level for different canopies

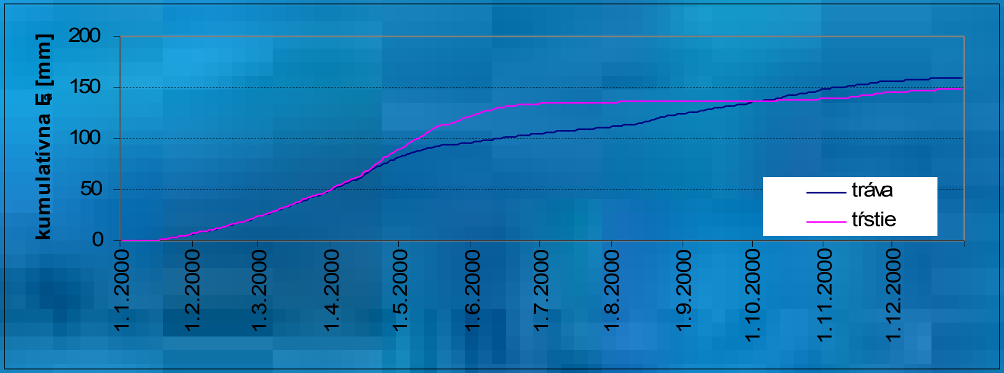
differences for grass and reed are observed during summer period



Cumulative seasonal ET and its components



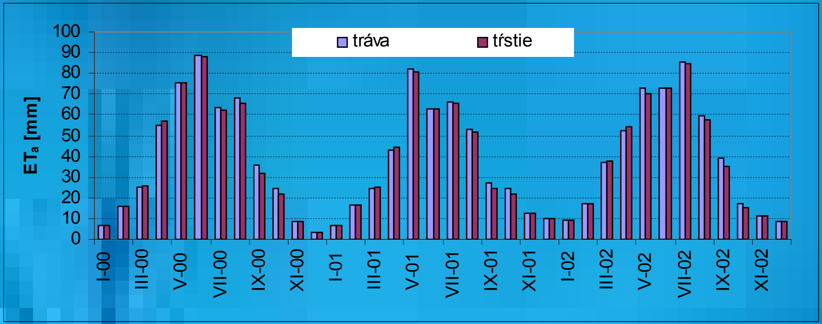


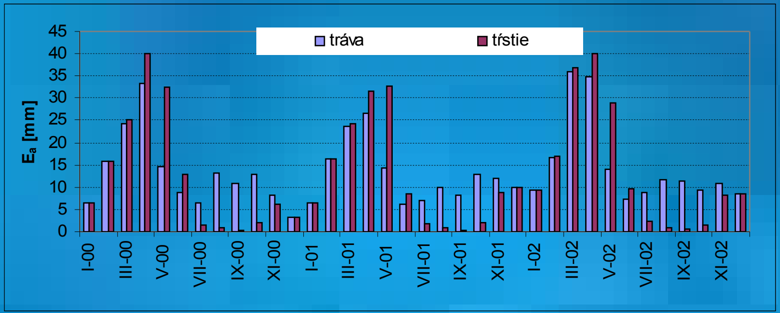


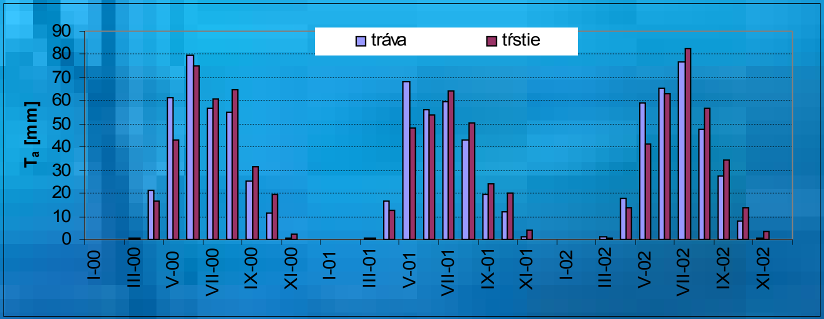
2000	Evaporation [mm]		Transpiration [mm]		Evapotranspiration [mm]	
	pot	*act*	*pot*	*act*	*pot*	*act*
Grass	159	159	312	312	472	471
Reed	149	148	315	315	465	464

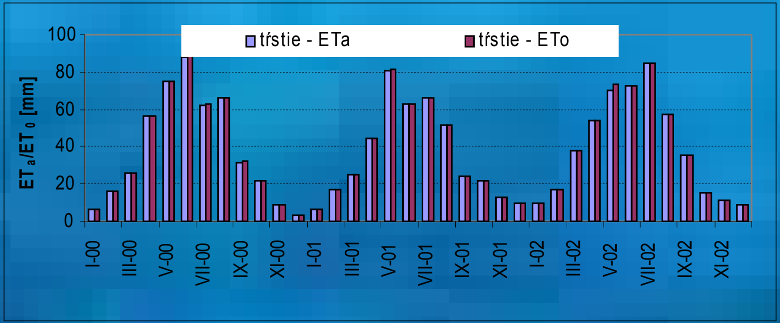
Kláštorské lúky

Monthly totals of ET and its components





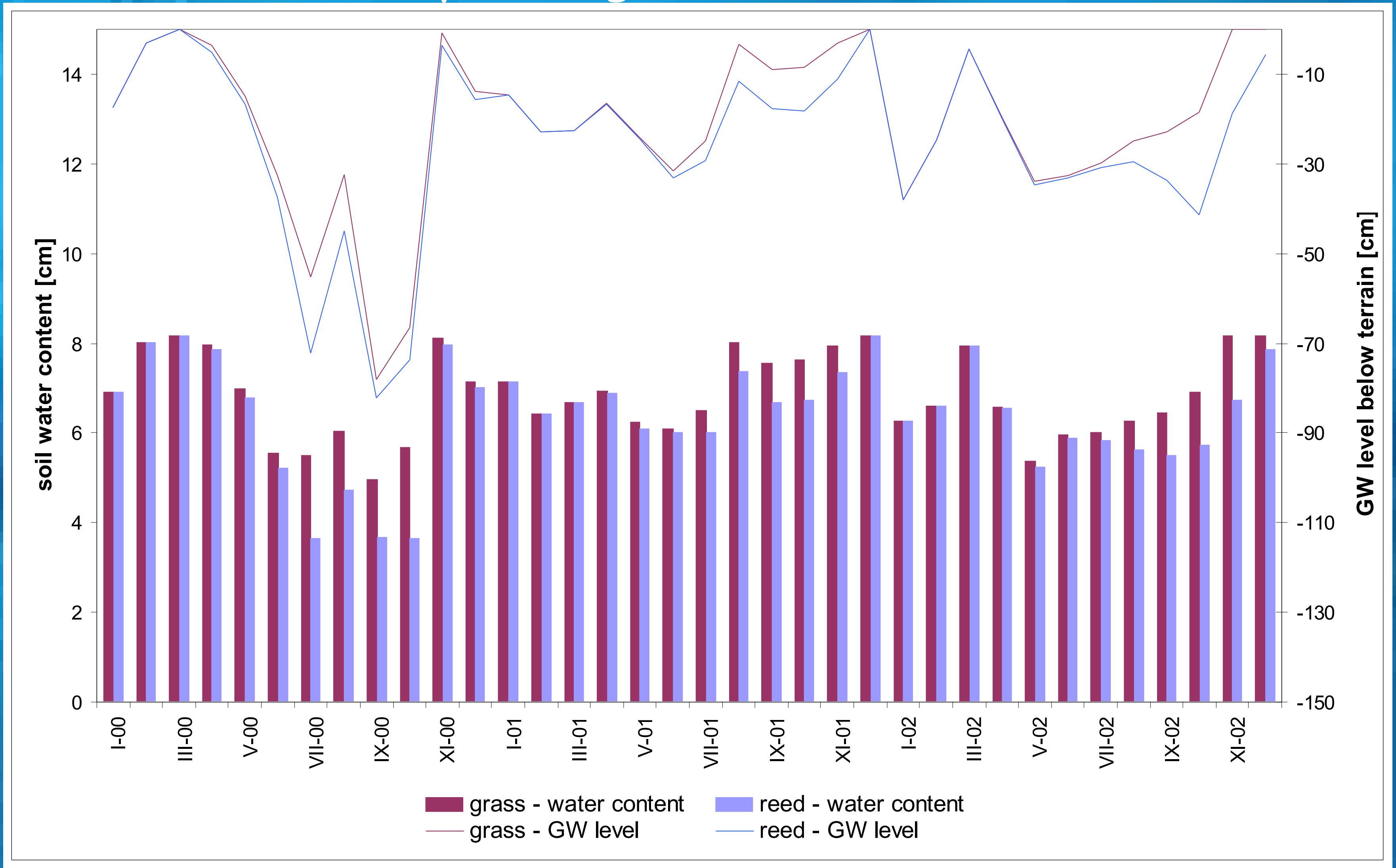




[mm]	2000		2001		2002	
	grass	reed	grass	reed	grass	reed
precipitation	648		735		813	
ET_a	471	464	429	422	482	474
E_a	159	148	153	144	178	164
T_a	318	315	276	278	304	310

Soil water content for reed and grass

Average SWC of soil layer 0-15 cm;
monthly average of GW level



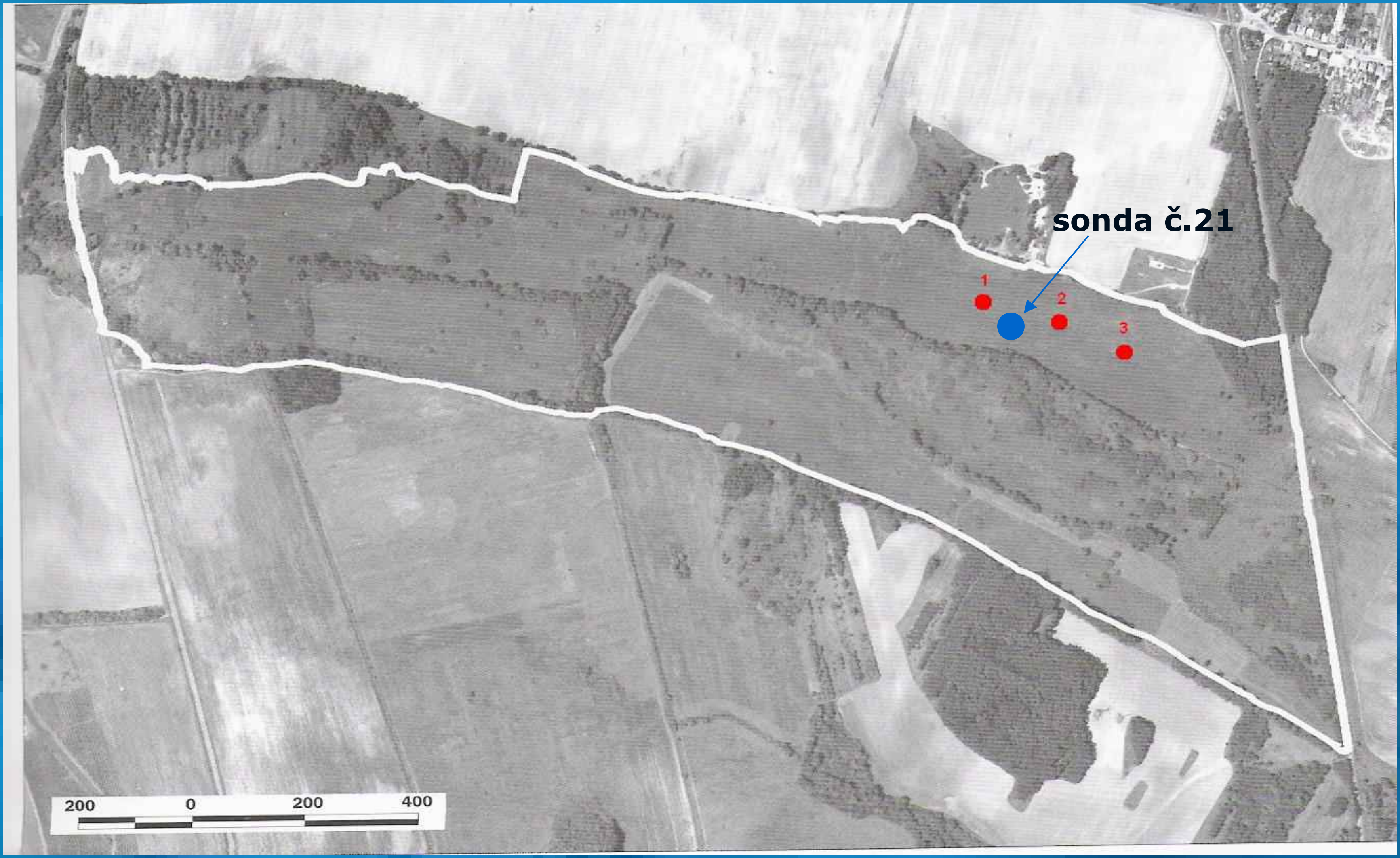
Abrod wetland
Effect of grass mowing

- ✓ the aim of wetland management is to preserve rare plant comunities
- ✓ regular mowing of grass
- ✓ mowing at the beginning of July (10.7.)
- ✓ effect of management type for:
  - ✓ without mowing
  - ✓ mowing once and twice per season (June 1. and August 1.)


N
W
E
S
PL
CZ
Abrod
UA
A
H
Žilina
Martin
Trenčín
Trnava
Nitra
BRATISLAVA
Banská
Bystrica
Prešov
Košice

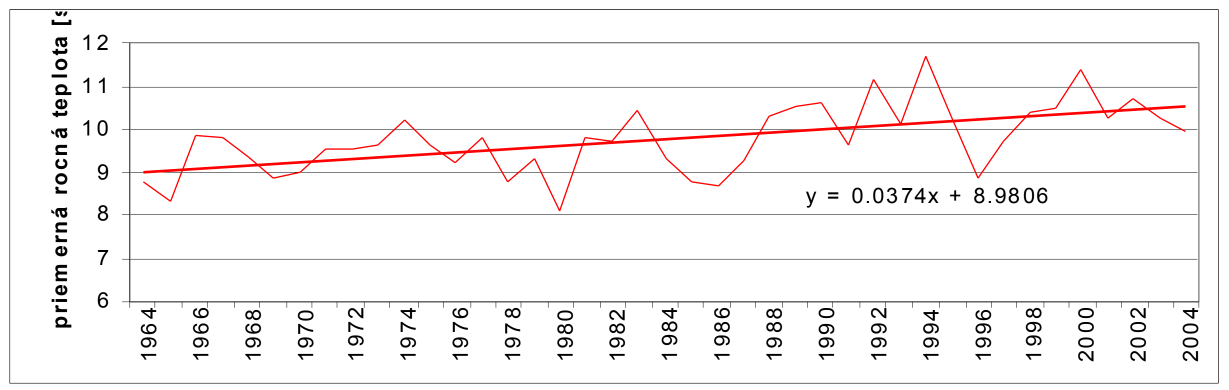
Abrod

Wetland Abrod



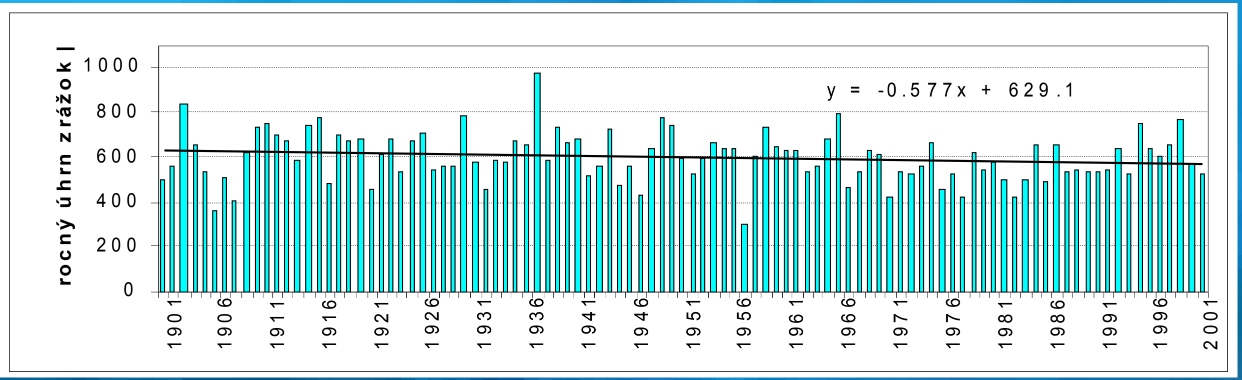
Meteorological data and GWT level

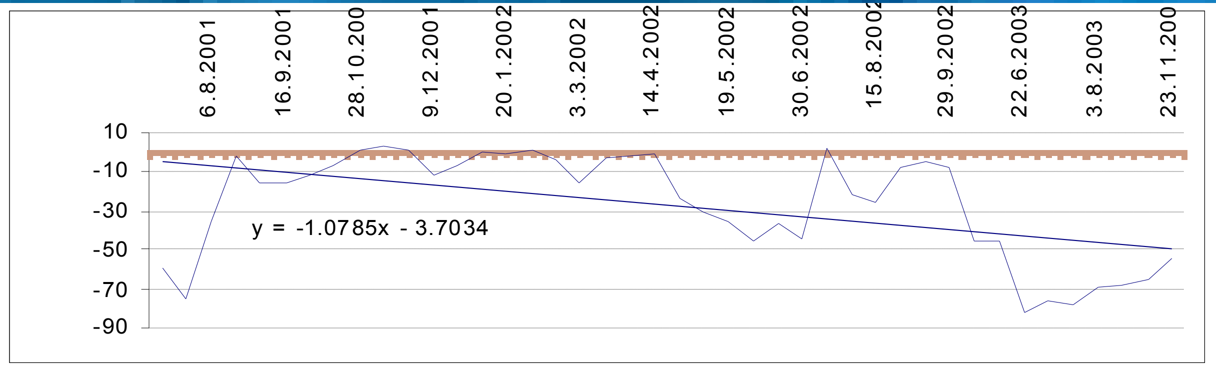
MS Kuchyňa



Air temperature
Annual average

Precipitation
Annual totals





GW level well N.21
Montly averages

Abrod

LAI measurement

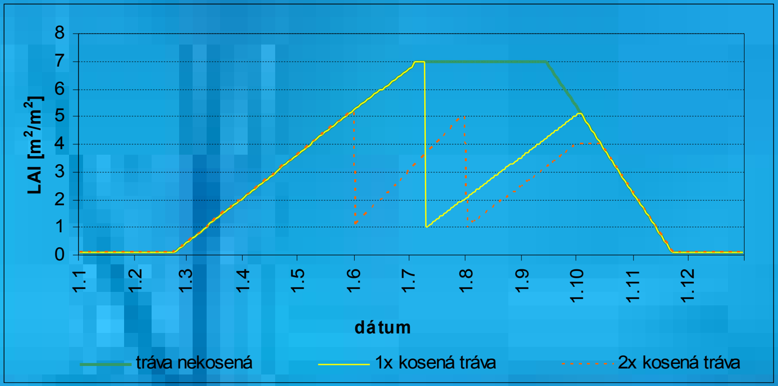
July, 3.

Canopy	LAI [m^2/m^2]
Grass	2.694
Sanguisorba officinalis (Krvavec lekársky)	0.063
Cirsium rivulare (Pichliač potočný)	0.174
Reed (Phragmites australis)	0.2216
Δ green reminders	0.2
Total	**3.35**

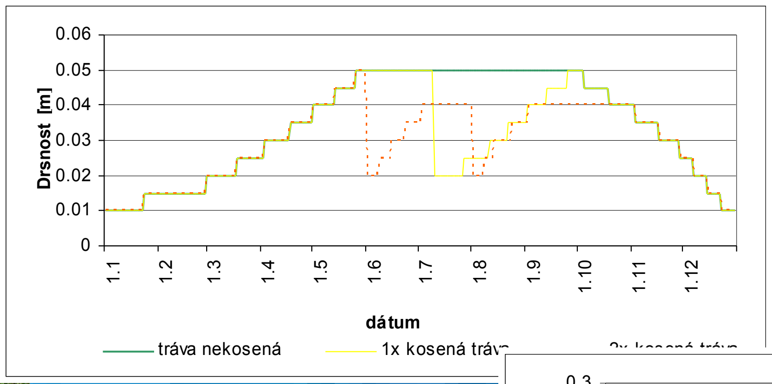
Abrod

Canopy characteristics

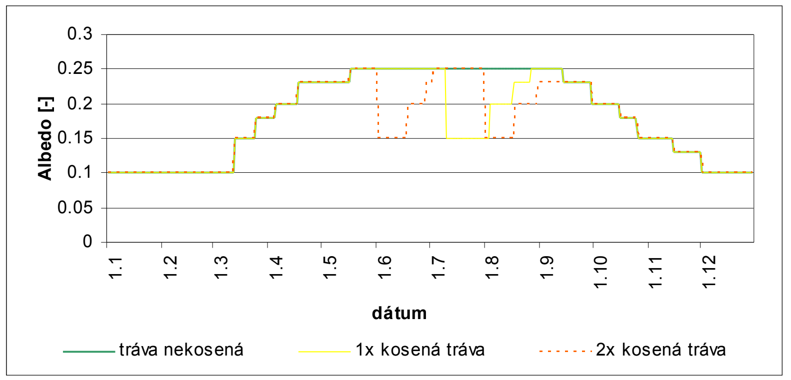
LAI



Roughness



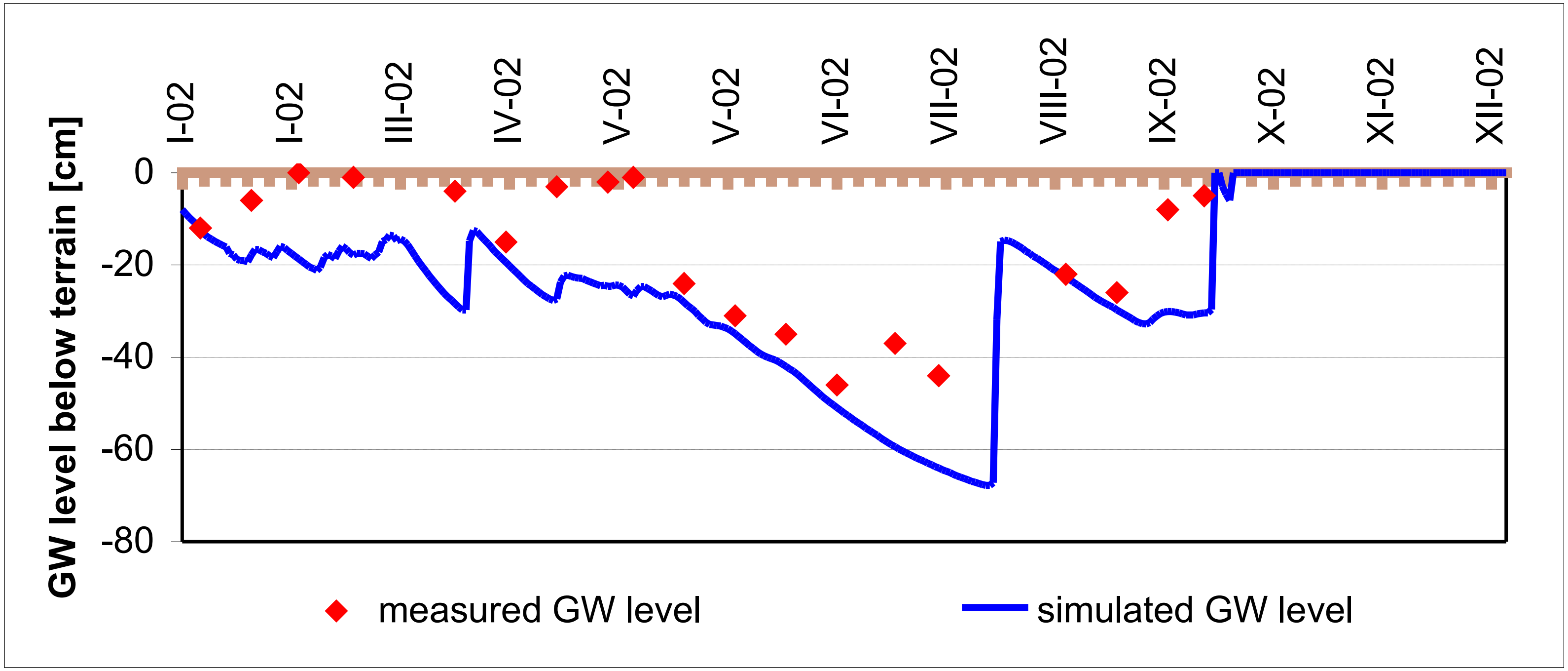
Albedo

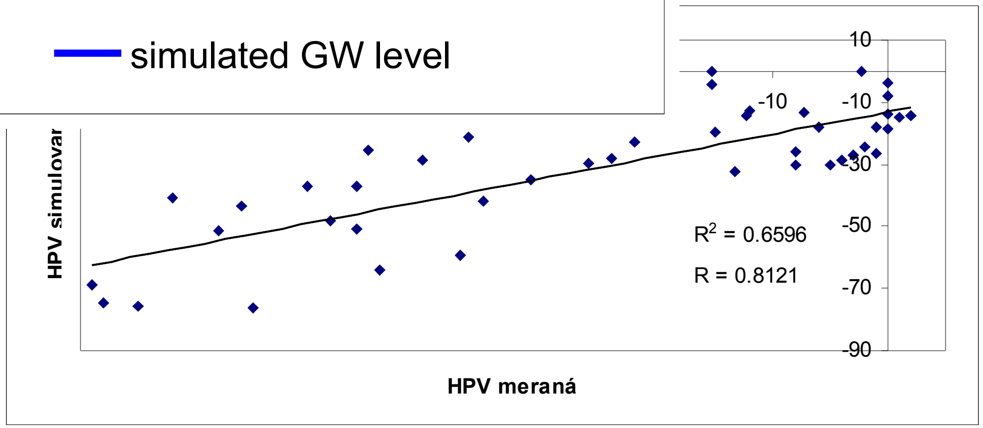


Abrod

Soil water regime simulation

- ✓ Comparison of measured and simulated GW level (model HYDRUS-ET)
- ✓ Model verification

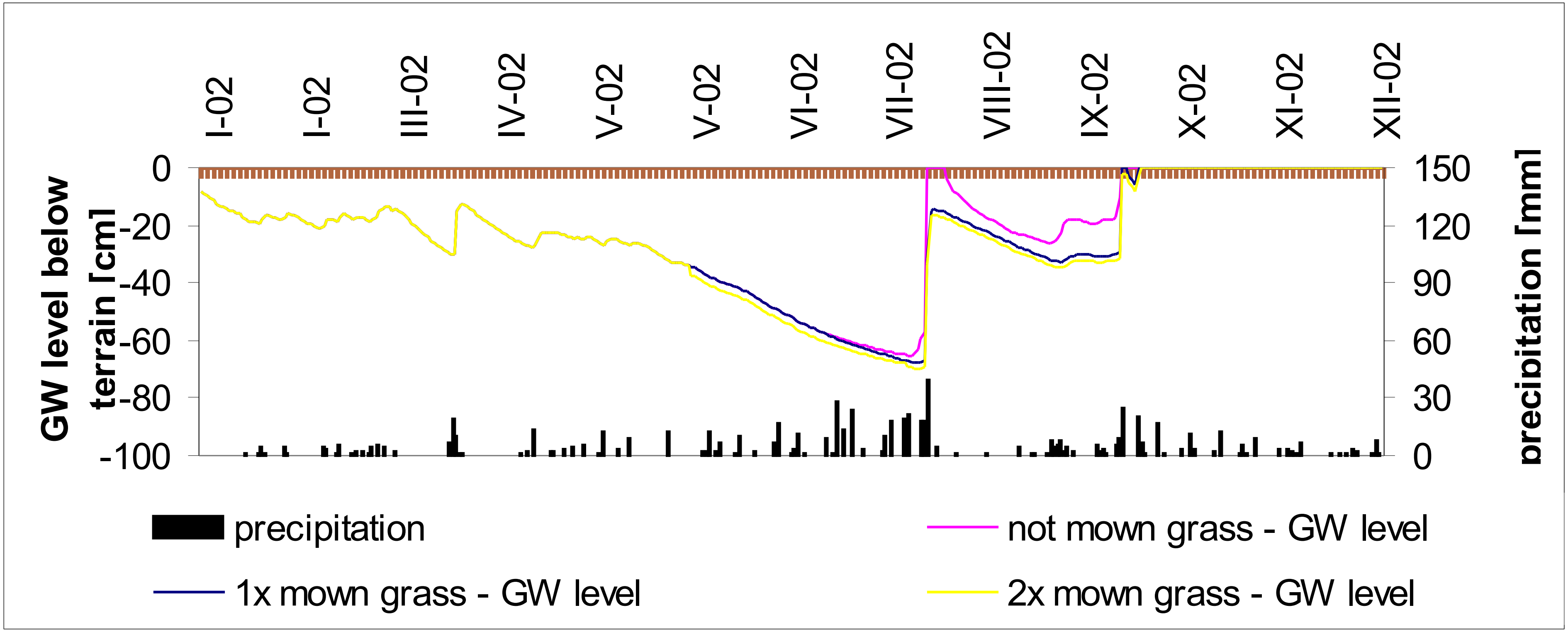




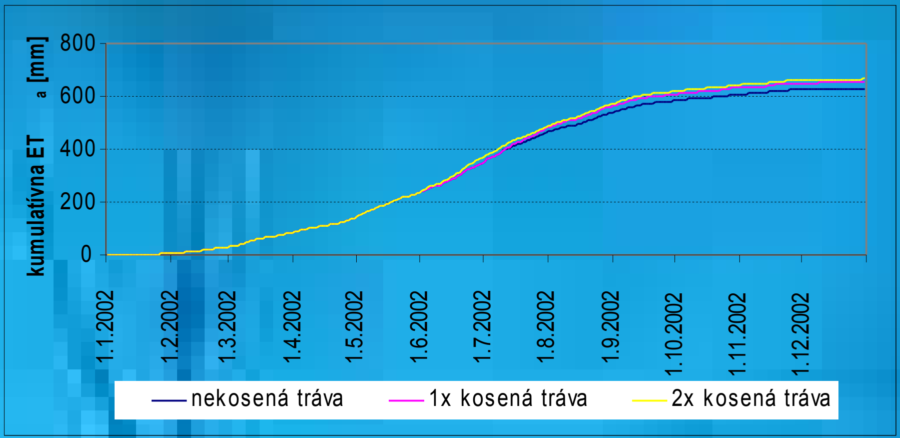
➢r = 0.81

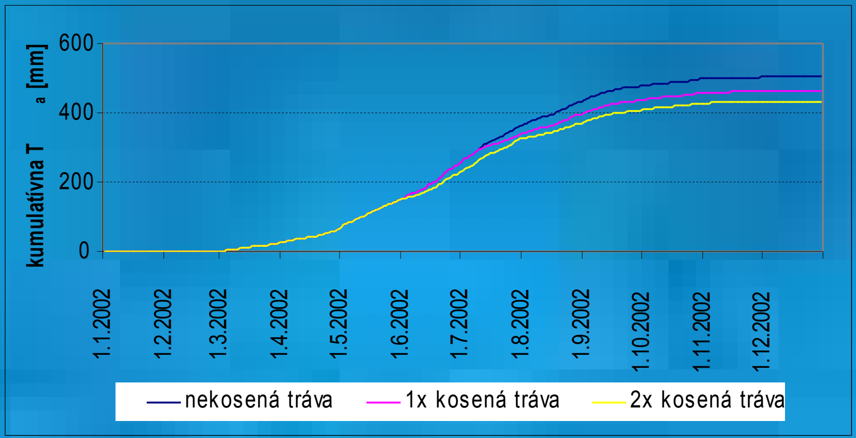
GW level for different management

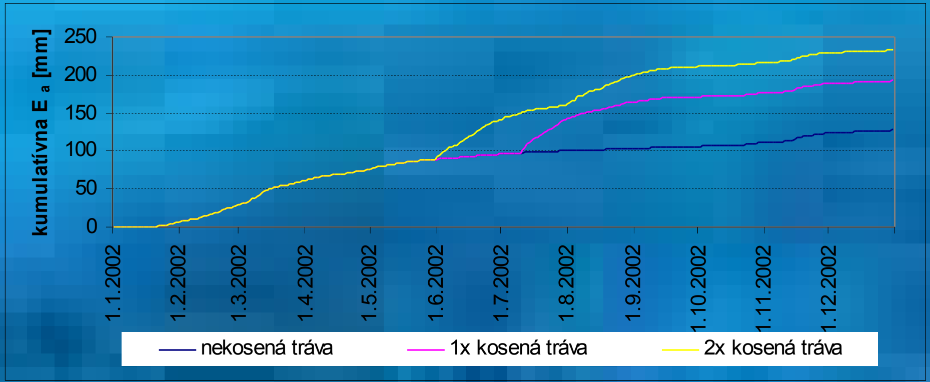
• maximum differences are in the period of maximum differences in canopy characteristics



ET and its components





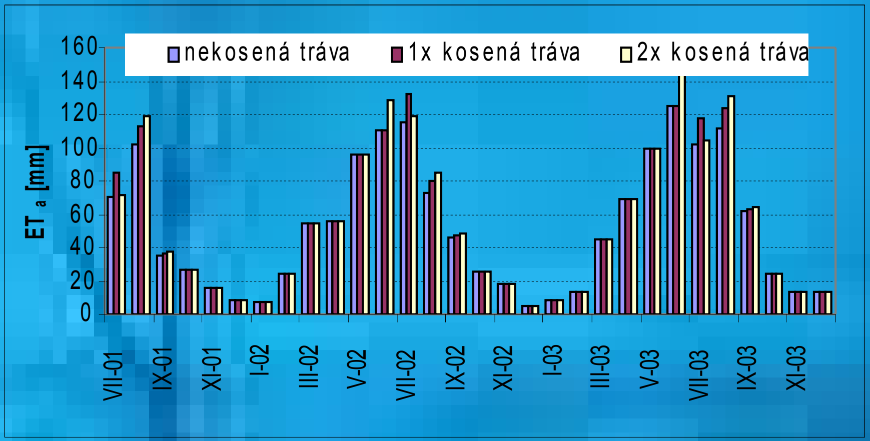


2002	Evaporation [mm]		Transpiration [mm]		Evapotranspiration [mm]	
	pot	*act*	*pot*	*act*	*pot*	*act*
Without mowing	128	128	503	503	631	631
1x mown grass	193	193	462	462	655	655
2x mown grass	234	234	433	433	667	667

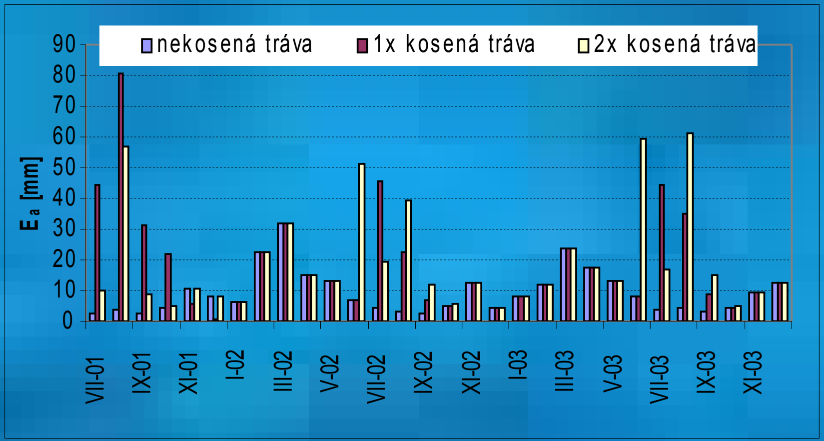
Abrod

Annual totals of ET and its components

ETa



Ea



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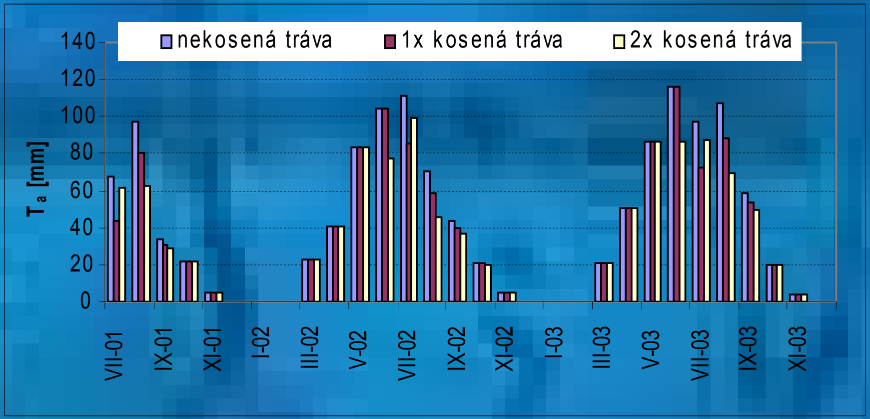
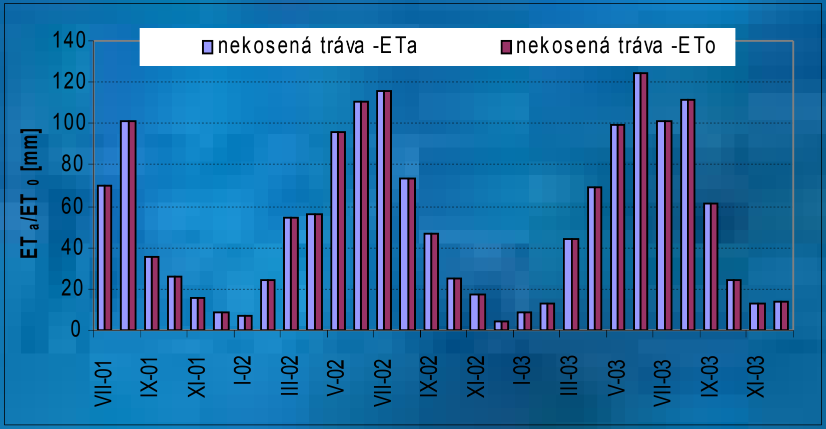


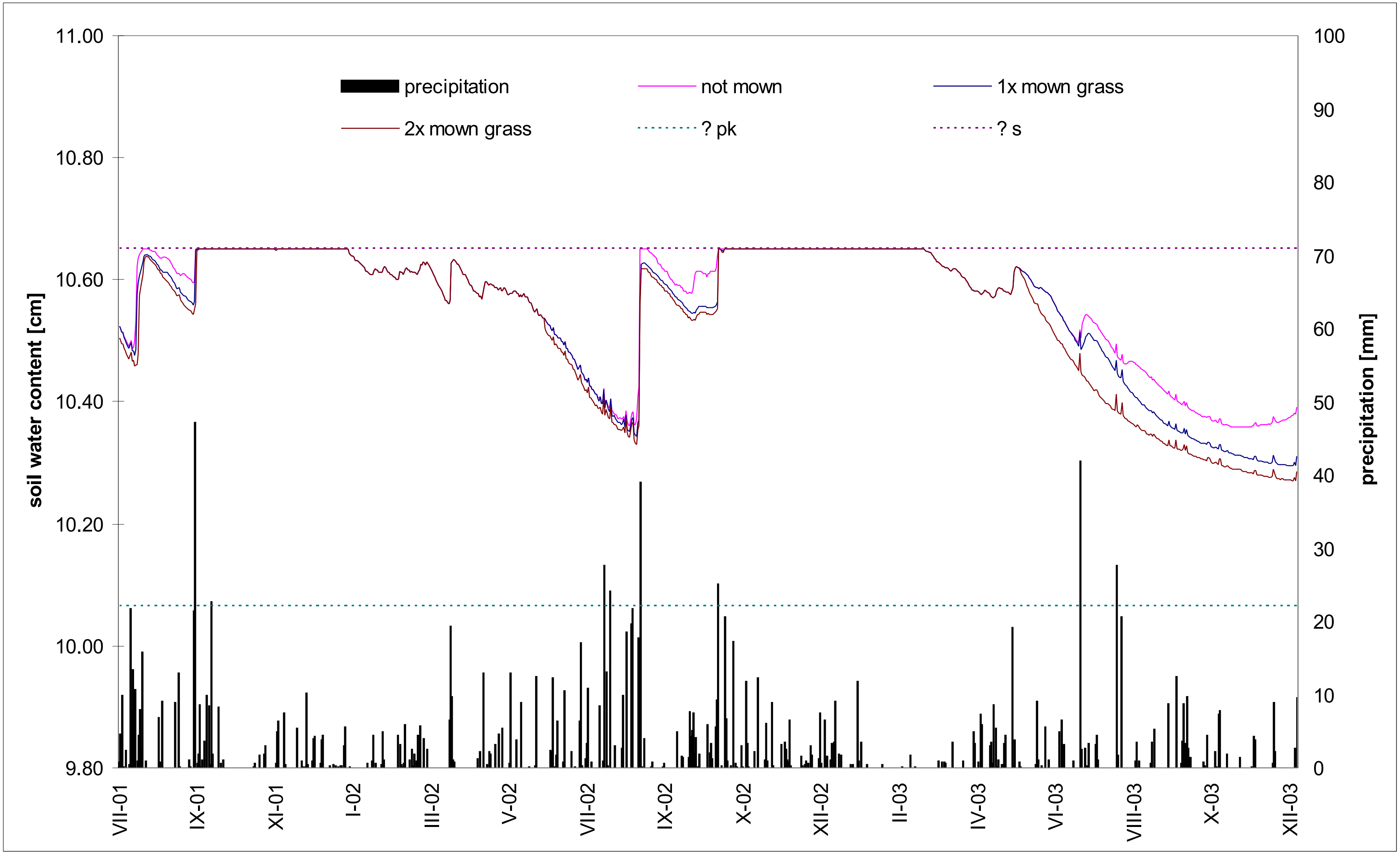
ETo/ETa



Abrod

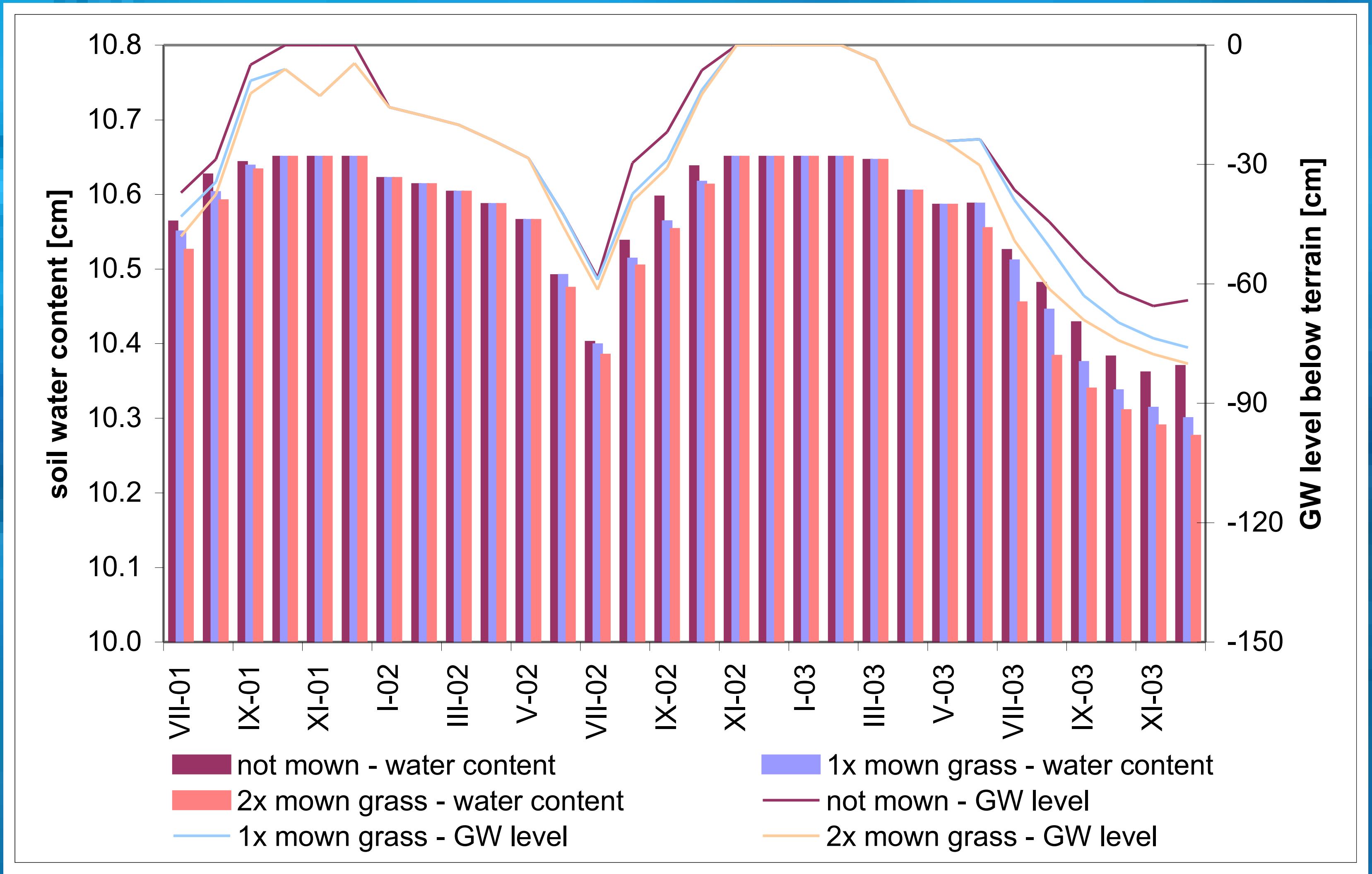
Soil water content

three soil layers: 0-15, 15-30, 0-50 cm



Soil water content

For mown grass once, mown grass twice and without mowing, corresponding GW level courses



Results - Kláštorské lúky

- ✓ **Kláštorské lúky – grass and reed canopy**
- ✓ Evapotranspiration annual totals of both alternative plant canopies were lower than annual precipitation totals
- ✓ The differences between GWT level under both canopies were found as non – significant (max. 20 cm)
- ✓ Transpiration of reed canopy was higher than from grass canopy during the summer period, therefore GWT level in this time was found deeper

Results – Abrod:
grass mowing and no management

- Changes in grass mowing (without mowing, once mowing, twice mowing) did not reflected significantly on annual totals of evapotranspiration (differences <5%)

- Significant changes were observed in evapotranspiration components: frequent mowing is increasing evaporation and decreasing transpiration

- GWT level changes during the vegetation period under different management practicies are not significant

General conclusions

- ✓ Management practicies can influence interactive processes among different canopies

- ✓ Different management practicies are influencing GW levels, but the differences are small, maximum differences are 20 cm; those differences are not critical for sustainable favourable conditions for wetland rare canopies

Recommendations for evaluation of wetland soil water regime

1. Appropriate mathematical (simulation model), suitable to evaluate wetland SWR (usually one dimensional simulation model, GLOBAL and HYDRUS –ET used in this study was found as appropriate, because of good evapotranspiration submodel formulation)
2. To ensure input data (meteorological, canopy, soil characteristics, initial and boundary conditions)
3. Identification or design of GWT observation well nearby
4. Soil water content measurement site
5. Soil hydrophysical characteristics estimation (measurement and calculation (by combination of field and laboratory methods (hydraulic conductivities, soil water retention curves and hydrologic constants)
6. Canopy characteristics (LAI, albedo, roughness, root parameters)
7. Simulation of SWR, verification of the model for particular site and results evaluation.

Thank you