Evaluation of Management-Dependent Changes in the Water Regime of Extensive Grasslands

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Abstract: The origin of the differences in the water regime components of 0–0.6 m soil profile was identified in extensively managed permanent grasslands (PG, variants: once cut – 1C, twice cut – 2C, nocut – NC, mulched June – MVI, mulched July – MVII) using the method of the soil water balance (drainage lysimeters). The differences in the water regime of the experimental variants manifested themselves depending on adequate soil water storage in the period when the amounts of transpiring biomass in individual variants differed markedly: (i) at the beginning of the vegetation period, when the surface litter in the NC and 1C variants reduced the actual evapotranspiration (ETA), (ii) at the time of mowing and mulching (M), when these treatments (mainly M) increased the soil water supply by ca 10–20 mm per month and decreased the ETA values by 1–2.5 mm per day for about 2–4 weeks as compared to non-mown variants on the given date, and (iii) as a result of the presence of different agrobotanical groups with distinct transpiration intensity (leguminous plants with a higher transpiration intensity in the 2C variant compared to grasses). The post-M reduction in evaporation was compensated by a higher total transpiration resulting from an increase in the aboveground phytomass. The lowest water consumption with the highest supply to the groundwater resources was recorded in the NC and 1C variants. The 2C variant containing leguminous plants with high water requirements had the highest consumption of water for evaporation and the lowest amount of water runoff from the soil profile. The identification of the water regime differences in individual variants helped determine the appropriate PG management with the aim to increase the underground water levels in the protection zones of water resources. The 1C variant of management is recommended mainly in the source areas of groundwater with lower productivity soils. In the accumulation areas of water resources (floodplain areas) with a deep soil profile and highly productive grassland, the 2C variant is required; mulching, which would largely support the yielding capacity of grassland, should be avoided. Mulching may occasionally be used as a relatively suitable method for the sites with a low yielding capacity in the source area.

Keywords: grasslands; extensive management; mulching; water regime; actual evapotranspiration; protection of water resources; lysimeters

The area of permanent grasslands in the Czech Republic (PG, e.g. 833 000 ha in 1991 and 971 000 ha in 2003) has increased significantly over the last 15 years as a result of the transformed agricultural production, and this trend is supposed to continue. Its main cause is grassing of arable land whose crops are less profitable, mainly due to a lower demand for feeding grains. Besides the production, all grasslands should fulfil the ecological, non-production roles, e.g. hydrological, soil conservation, protective-filtration, and aesthetic functions. The hydrological function is of key

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importance, particularly in the protection zones of water resources (PZWR), which significantly contribute to the formation of resources for drinking water supplies. In the infiltration (source) areas of PZWR (ČSN 736532 1987), the hydrogeological structure undergoes significant water infiltration, while large volumes of groundwater accumulate in the accumulation area. The hydrological function of PG resides in the retention of a relatively high amount of precipitation in its soil profile (in mown grasslands 11–25% of the annual amount, Mrkvička *et al.* 1998) and minimisation of the surface runoff (Hejduk & Kasprzak 2004a, b) during the vegetation period thanks to a higher content of organic matter, good soil structure, and porosity (Jůva *et al.* 1975; see in Rychnovská *et al.* 1985). Resulting from a low soil compaction and a lower absolute water consumption through evapotranspiration compared to the intensively managed PG, this hydrological function should be supported by appropriate PG management through extensive or semi-intensive use of meadows (cut once or twice a year) and pastures (Kvítek *et al.* 2004) that should remain sufficiently dense, rich-in-species PG with a lower biomass yield. Reduced evaporation should increase the water runoff to the groundwater resources.

In the last decade, reduced stock breeding along with a lower fodder request brought about the introduction of a modified pratotechnique for grasslands – mulching: the grass is mown, the biomass cut to particles and left on the site to decompose. In practice, mowing and mulching can be combined, e.g. as needed for forage in a given year. It is, however, impossible to leave PG unused, mainly due to the negative impact on their botanical composition and aesthetic or biofiltration function.

The objective of the present paper was to determine the conditions causing differences in the water regime of grasslands depending on their management (including mulching) and to define the type of management with maximum water retention in the soil and in the landscape.

MATERIAL AND METHODS

Description of experimental locality, soil profile, experimental design

The experimental plot is situated in the cadastre of the municipality of Klečaty near Veselí nad Lužnicí (Figure 1); in geomorphological terms, located in the Třeboň Basin, 423 m above s.l. The climatic region is moderately warm (district B 3 – moderately warm, moderately humid, with mild winters, of upland type). The standard precipitation and temperature (1. 1. 1961–31. 12. 1990) for Borkovice (Czech Hydrometeorological Institute) is 596 mm and 7.2°C, and the respective values in the vegetation period are 388 mm and 13.3°C. The location concerned is an agricultural area with

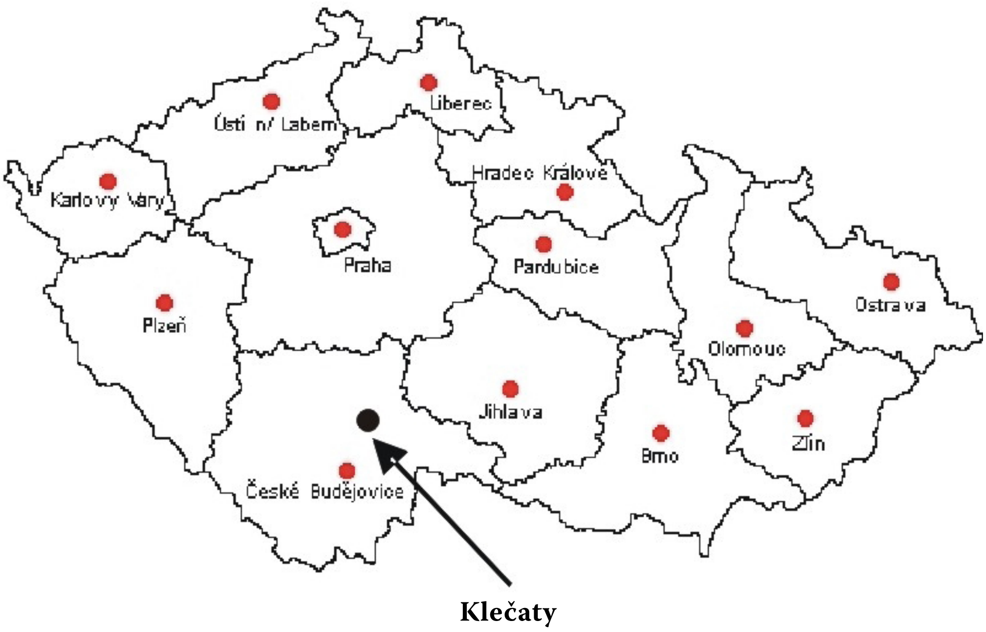

Figure 1. Location of the experimental plot Klečaty

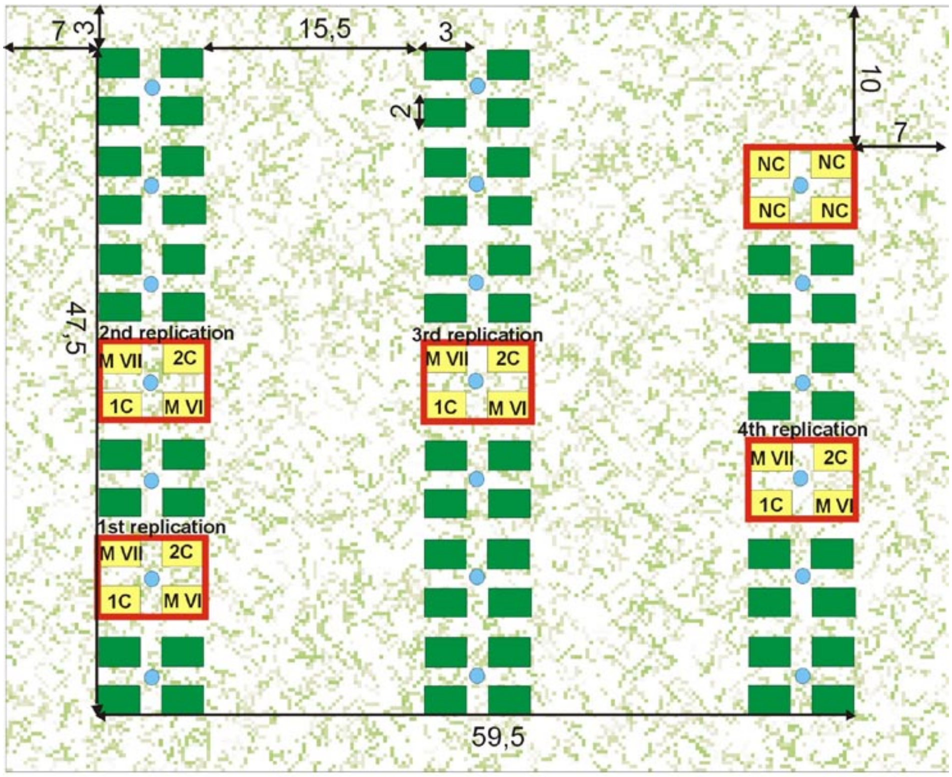

Figure 2. The experimental plot design (sizes given in m)

cereal production, soil type: pseudogley Luvisol, texture: sandy-loam to clayey loam, soil-forming substrate: loess loam. Geologically, these are sandy and clayey Tertiary sediments.

To evaluate the water regime of extensively used grasslands, five experimental variants were studied in a random block design with four replicates in the locality of the Klečaty lysimetric station (Figure 2). The area of an experimental parcel was 2 × 3 = 6 m^2, the area of a variant with four replicates was 4 × 6 = 24 m^2. All plots had been unfertilised since 1993. The experimental variants were as follows:

once cut – 1C (cut in mid-July),

twice cut – 2C (first cut in May/June, second in mid-September),

once cut and mulched – MVI (mulched in May/June, since 2000),

once cut and mulched – MVII (mulched in mid-July),

long-term nocut – unused land – NC.

The water regime components (precipitation, actual evapotranspiration (ETA), soil water content, runoff of infiltrated water from the soil profile) were determined in the experimental plot using the method of the soil water balance. For this purpose, 0.71 × 0.71 m (0.5 m^2) drainage lysimeters (PVC-U dishes) were placed 0.6 m below the soil surface in 1976. The lysimeters were covered with soil layers copying the soil horizons. Percolating water is conducted from the lysimeter with a pipe to a PVC bottle. The bottles are accessible in 1.5 m deep wells that are drained with drain pipes laid at a depth of 1.7 m. In the vegetation period, soil moisture by weight was determined in the soil layers 0–0.1; 0.1–0.2; 0.2–0.3; and 0.3–0.6 m regularly at fortnight intervals (gravimetric method) in each management variant in four replicates and converted to soil moisture by volume by means of bulk density. Water storage of the 0–0.6 m soil profile was then determined; the measurements of precipitation and water runoff from the soil profile to the PVC bottles were done simultaneously. The data was applied to calculate the ETA value for 0–0.6 m soil profile during the preceding fortnight:

$$\mathrm{ETA} = Hs - O + W_1 - W_2 \qquad \text{(mm)}$$

where:

ETA – actual evapotranspiration in the period of observation

Hs – precipitation in the period of observation

O – volume of water percolating through the soil profile in the period of observation

$W_1 - W_2$ – the difference in soil moisture by volume between the beginning and the end of the observation period

Table 1. Evaluation of the normality of average air temperature (*Ta*) and precipitation sum (*Hs*) in vegetation periods (in comparison with the CHMI Borkovice 1961–1990 standard)

Year	1998	1999	2000	2001	2002	2003	2004
Ta (°C)	EAN	EAN	EAN	N	AN	EAN	N
Hs (mm)	N	BN	BN	HAN	HAN	HBN	N

HBN – highly below-normal period, BN – below-normal period, N – normal period, AN – above-normal period, HAN – highly above-normal period, EAN – extremely above-normal period

The sub-surface and surface run on and runoff were not taken into account because of the almost flat terrain. The sum of the fortnight ETA values in the period beginning in April up to the second half of September provided the value of actual evapotranspiration during the vegetation period (ETA sum).

To test statistically the hypothesis that the average water regime components of the individual variants correlate, one-way analysis of variance (ANOVA) at a significance level $\alpha = 0.05$ and Scheffe's multiple range test were used in Statgraphics version 7.1 software.

RESULTS AND DISCUSSION

The water regime of extensively used grasslands is dependent on the overall effects of climatic, soil, and anthropogenic factors, including the management method (Grace 1983; Penka 1985; Matejka & Huzulák 1987; Dykyjová *et al.* 1989; Novák 1995; Procházka *et al.* 1998).

In the years with highly above-normal precipitation (2001, 2002, Figure 3, Table 1), the precipitation sum for the entire vegetation period exceeded the ETA sum. The grassland was sufficiently supplied with soil moisture and did not have to restrict substantially the water loss by regulating stomatal conductivity. The differences in the botanical composition of the management variants enabled a better distinction between their transpiration and/or evapotranspiration. During the precipitation periods (with a decreased water saturation deficit), the ETA sum value dropped, and the water unused for evaporation drained into groundwater resources, especially in the periods of long-term or intensive precipitation. In the years with below-normal or highly below-normal precipitations (1999, 2000, 2003, Table 1), the ETA sum for the vegetation period highly exceeded the

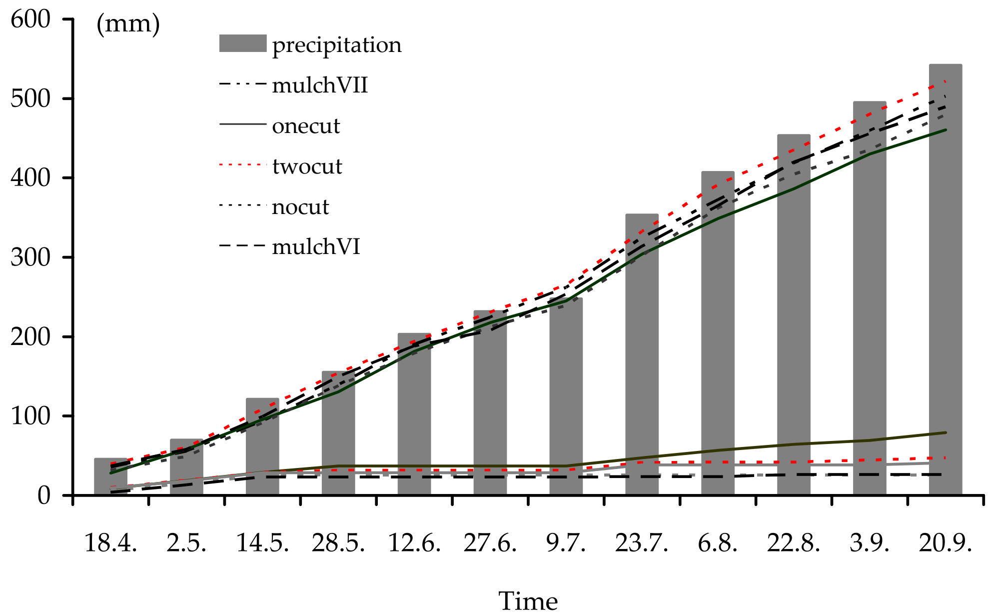

Figure 3. Cumulative sum of precipitation, ETA and runoff water (mm) in individual variants, Klečaty 2001 (year with highly above-normal precipitation)

sum of precipitation, which indicates that water for evaporation was depleted from the soil water storage (Table 5). As a general rule, in dry years the grassland ETA is limited by the deficiency of water for evaporation, while in wet years, with no lack of water, the evaporation process is restricted by the radiation balance.

The differences in the water regime of grasslands originated from the sufficient water storage in the soil (i.e. 120–150 mm in the 0–60 cm soil profile) in the period with varying quantity of transpiring biomass in the individual variants. This was seen (i) at the beginning of the vegetation period, (ii) at the time of cuts and mulching, and (iii) due to the presence of different agrobotanical groups with distinct transpiration intensity.

(i) At the beginning of the vegetation period, the differences in the water regime of the experimental variants were influenced by the grassland structure, when the NC variant (or 1C variant) was extensively covered by surface litter with non-productive transpiration. Consequently, the soil in this variant warmed up more slowly and the regrowth started much later (the beginning of May) compared to the mown variants. The presence of surface litter decreased the utilisation of the radiation energy for evapotranspiration in favour of the turbulent heat flux (Tappeiner & Cernusca 1998; Cernusca *et al.* 1998). It may be concluded that at the beginning of the vegetation period (mid-May–late May), the ETA sum of the NC variant was lower than those of other variants (mean ETA sum from early April to late May in 1998–2004: MVII: 116.2; 1C: 112.6; 2C: 118.0; NC: 110.3 mm, in 2000–2004: MVII: 123.1; 1C: 116.6; 2C: 125.3; NC: 121.5 mm). The results document that at the beginning of the vegetation period, ETA of the 1C variant was very similar to ETA of the NC variant due to the presence of surface litter and the relatively lower volume of transpiring biomass (without leguminous plants and increased yield by mulching). In the high vegetation period, the ETA sum of the NC variant relatively increased compared to the other variants since its transpiration was not reduced by the biomass removal.

(ii) The effect of cuts and mulching on the water regime depends on the meteorological conditions before and after the cuts. In extreme situations of long droughts or rich rainfalls, both treatments had a low effect on the increase in the soil moisture as compared to the non-mown variants on the given date. Almost no reduction in ETA or a maximum of 0.7–1 mm per day for 2–4 weeks was observed. In a rainless period, this can be explained by limited evaporation from the soil due to insufficient soil water storage in all variants. Accordingly, in a longer rainfall period, evaporation from all variants was restricted due to the low water saturation deficit. With the soil profile abounding with moisture during the mowing period or with a rainfall shortly after the cut followed by a warm rainless period, the water regime of the particular

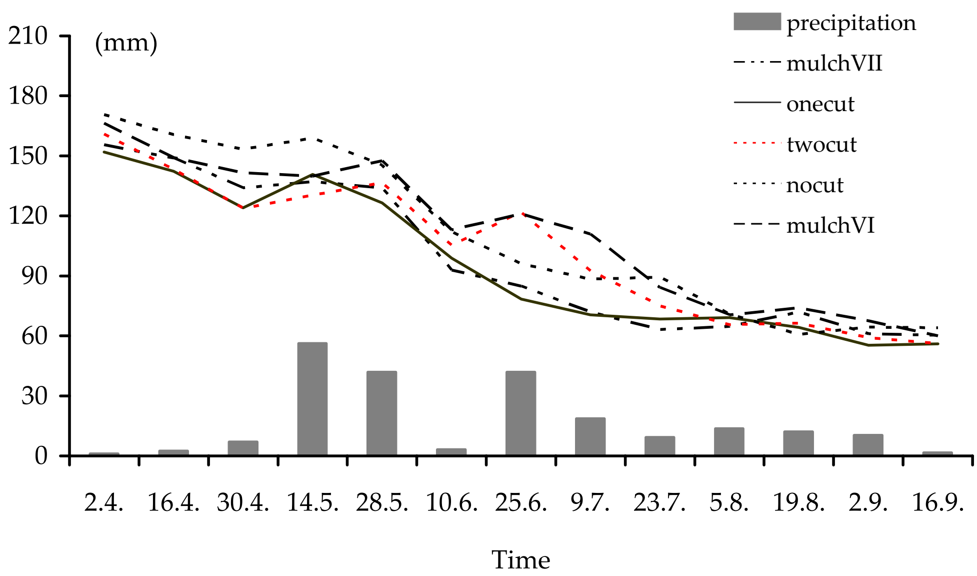

Figure 4. Dynamics of soil water storage (0.0–0.6 m) in individual variants, Klečaty 2003

Table 2. Sum values of actual evapotranspiration (mm) and average values of water storage (mm) of 0–0.6 m soil profile in individual variants, Klečaty vegetation period (early April–2nd decade of September 1998–2004)

Year	Variant									
	1C	2C	MVI	MVII	NC	1C	2C	MVI	MVII	NC
	actual evapotranspiration in the vegetation period					soil water storage in the vegetation period				
1998	361.4	371.8		359.4	371.8	137.2	132.9		130.9	144.5
1999	328.9	335.2		335.6	320.7	125.7	127.1		124.2	124.2
2000	349.4	368.4	356.4	351.5	351.7	116.2	113.5	116.4	109.4	132.7
2001	460.5	521.5	489.4	503.1	479.2	155.4	158.2	148.0	148.3	154.4
2002	431.8	436.5	430.5	431.7	437.9	136.8	138.2	144.4	148.0	150.9
2003	310.5	321.3	324.1	313.2	316.3	95.9	102.8	111.2	98.5	110.4
2004	410.9	407.2	391.2	395.3	377.5	131.5	129.1	124.8	134.6	131.3
1998–2004	2653.4	2761.9		2689.8	2655.1	128.4	128.8		127.7	135.5
2000–2004	1963.1	2054.9	1991.6	1994.8	1962.7	127.2	128.4	129.0	127.8	135.9

1C – once cut, 2C – twice cut, MVI – mulched May/June, MVII – mulched in July

variants depended on the management method more significantly. The removal of the transpiring biomass or spreading the mulched biomass after mowing and mulching caused an increase in soil water storage by 10–20 mm (Figure 4, 25. 6. 2003) for a month and a decrease in ETA values by 1–2.5 mm per day for a transient period of at least 2–4 weeks compared to the non-mown variants on the given date (Figure 5, 25. 6. 2003). The management-dependent preservation of the soil moisture was always higher in the mulched variants than in the mown variants.

The reduced post-M evaporation was only transient (similarly as in Kvítek *et al.* 1998) and was compensated during the entire vegetation period (Table 2) e.g. by increased transpiration in variant MVII in correlation with a higher amount of phytomass in this variant compared to the 1C variant (in mulched variants, a marked dry phytomass increase was observed from ca the 5th year of mulching, Table 6).

Mulching once a year on two dates thus caused no reduction in ETA sum values and no increase in soil water storage or water runoff from the soil

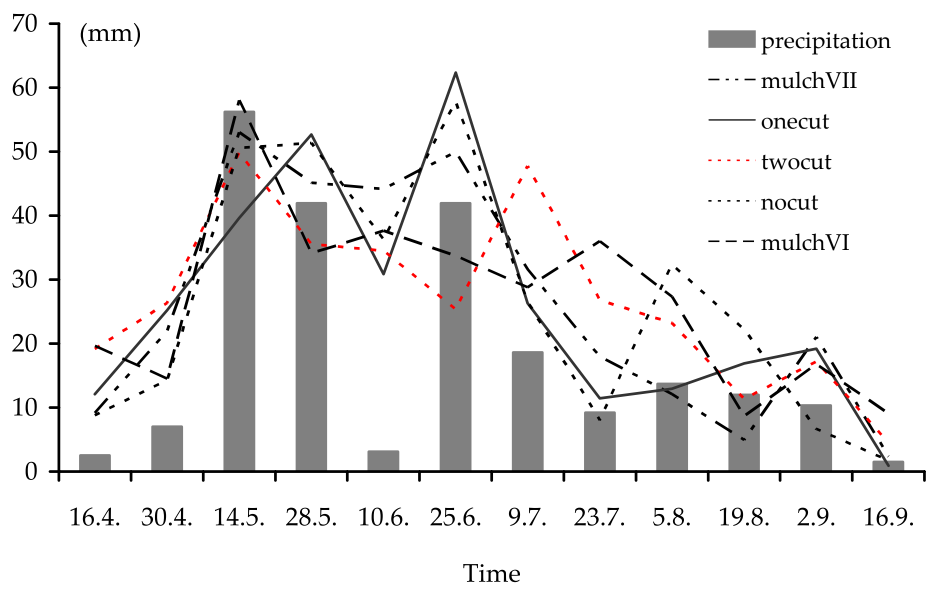

Figure 5. 14-day values of ETA in differently managed grasslands, Klečaty 2003

Table 3. Sum values of precipitation and water runoff from 0.0–0.6 m soil profile (mm) in individual variants, Klečaty vegetation period, 1998–2004

Year	Variant					Precipitation in the vegetation period
	1C	2C	MVI	MVII	NC	
	water runoff in the vegetation period					
1998	1.4	0.1		0.1	3.7	347.7
1999	1.5	2.5		0.1	2.9	237.9
2000	6.7	6.2	2.3	0.1	9.1	300.1
2001	78.8	26.0	41.1	26.2	47.2	542.6
2002	160.0	155.8	142.3	154.4	140.5	570.7
2003	3.3	1.1	0.0	0.0	8.2	217.9
2004	37.3	39.1	49.0	45.5	67.7	358.9
1998–2004	289.0	230.8		226.4	279.3	2575.8
2000–2004	286.1	228.2	234.7	226.2	272.7	1990.2

profile in the vegetation period compared to the mown variants. It is, however, possible that a more substantial soil moisture economy can be achieved through a higher mulching frequency.

(iii) The water regime in individual variants differed in the years with normal to highly above-normal precipitation in all months of the vegetation period, especially if good management and favourable climatic conditions led to the presence of an agrobotanical group with a distinct transpiration intensity and phytomass growth (Table 4). This was observed in the 2C variant, where a significant proportion of leguminous plants occurred (Gaisler *et al.* 2004) in 2001 with above-normal precipitation (before the 1st cut, 19% of *Trifolium pratense*, 6% of *Trifolium repens*, and 36% of *Trifolium dubium*). The ETA sum of the entire vegetation period exceeded that of the 1C variant by 60 mm (75–95% of grasses, statistically significant difference at $\alpha = 0.05$ significance level). Higher water requirements of leguminous plants compared to grasses is the main reason for this difference (transpiration coefficients: leguminous plants 800–1200, grasses 700–800), not being restricted by stomatal regulation in the years with above-normal precipitation. In extensive conditions, leguminous plants give higher yields than grasses (Misztal 1999; Mrkvička written communication 2005). When the proportions of leguminous plants were only negligible in all variants, though the relevant months of the vegetation period had normal to above-normal precipitation (2004), the transpiration differences could correlate more easily with the plant species and yield. The difference between the maximum (1C) and minimum (NC) values of total evapotranspiration was 33 mm (Table 2).

If some months or the entire vegetation period was evaluated as having below-normal to extremely below-normal precipitation, the differences in total ETA between the variants were relatively small due to transpiration restricted by stomatal regulation (12–19 mm), regardless of different yields or botanical composition. In this case, the representation of leguminous plants had no impact on the increased canopy water consumption.

The evaluation of the significance of total ETA differences during the vegetation period indicated a difference between the 2C variant on one hand and the NC and 1C variants on the other in the period of 1998–2004, and between the 2C variant and the other variants in the years 2000–2004. A significant runoff of water from 0–0.6 m soil profile to the groundwater level was seen only in the vegetation periods with normal to highly above-normal precipitation (Table 3) and it correlated negatively with the ETA sum. In the vegetation period with a highly below-normal to normal precipitation, a critical amount of precipitation (almost 100%, Table 5) is transmitted through evapotranspiration to the atmosphere.

The evaluation of the summed values of infiltrated water in the entire period of 1998–2004 showed differences between the 1C variant on one

Table 4. Proportions of agrobotanical groups (%) in individual variants and years, Klečaty 1998–2004

Variant/agrobotanical group	Year						
	1998	1999	2000	2001	2002	2003	2004
Mulched in July							
Monocotyledons*	73	88	79	90	98	97	89
Dicotyledons (leguminous)	0	0	+	+	+	+	4
Other dicotyledons	+	+	2	3	1	1	7
Surface litter + voids	27	12	19	7	1	2	0
Mulched in June							
Monocotyledons*			75	75	85	89	90
Dicotyledons (leguminous)			+	+	0	0	+
Other dicotyledons			5	12	2	5	8
Surface litter + voids			20	13	13	6	2
One cut							
Monocotyledons*	41	58	60	73	86	80	75
Dicotyledons (leguminous)	0	+	5	2	+	3	5
Other dicotyledons	26	30	16	15	14	15	18
Surface litter + voids	33	12	19	10	0	2	2
Two cuts							
Monocotyledons*	54	34	11	21	54	70	80
Dicotyledons (leguminous)	6	28	75	61	21	13	6
Other dicotyledons	26	27	12	17	23	6	11
Surface litter + voids	14	11	2	1	2	11	3
Nocut							
Monocotyledons*	57	72	51	61	68	71	83
Dicotyledons (leguminous)	0	1	0	0	0	+	0
Other dicotyledons	43	21	22	22	16	16	12
Surface litter + voids	10	6	27	17	16	13	5

*grasses, sedge family, rush family

hand (289 mm) and 2C and MVII on the other (231; 226 mm), whereas in the period of 2000–2004, differences were seen between the 1C variant (286 mm) and 2C, MVI, and MVII variants (228; 235; 226 mm). The amount of runoff from the NC variant was very similar to that in the 1C variant (1998–2004: 279 mm; 2000–2004: 273 mm).

The highest soil water storage of the NC variant (Table 2) was caused partly by a higher loss of the water balance components of the mown and mulched variants, but partly also by the highest value of soil water storage of the NC variant at the beginning of the vegetation period. This led to significant differences between soil water storage of the NC variant and some other variants in certain years (1998, 2000, 2002) and in the period of 2000–2004.

Table 5 defines the utilisation of water sources (precipitation, soil water storage) for evaporation, i.e. for the ETA process. The contribution of precipitation to the evapotranspiration process is dependent on the meteorological conditions, but is still decisive (70–100%, lower limit in years with below-normal to highly below-normal precipita-

Table 5. Definition of water sources for evaporation (0.0–0.6 m soil profile), Klečaty vegetation period, 1998–2004

Year	Precipitation (mm)	ETA (mm)	Runoff (mm)	ETA from soil storage, mm (%)	ETA from precipitation mm (%)	Precipitation utilisation for ETA (%)	Evaluation of precipitation normality
1998	347.7	367.4	1.0	20.7 (5.6)	346.7 (94.4)	99.7	N
1999	237.9	330.1	1.7	93.9 (28.4)	236.2 (71.6)	99.3	BN
2000	300.1	355.4	4.9	59.3 (16.7)	296.1 (83.3)	98.7	BN
2001	542.6	490.8	43.9	0 (increase by 7.9)	490.8 (100)	90.5	HAN
2002	570.7	433.6	150.6	13.5 (3.1)	420.1 (96.9)	73.6	HAN
2003	217.9	317.0	2.5	101.6 (32.1)	215.4 (67.9)	98.9	HBN
2004	358.9	396.4	47.7	85.2 (21.5)	311.2 (78.5)	86.7	N

HBN – highly below-normal, BN – below-normal, N – normal, HAN – highly above-normal period

tion, upper limit in years with highly above-normal precipitation). The remaining ETA proportion is obtained from soil water storage (0–30%).

Over the entire observation period, the 1C and NC variants appeared to be the most economical in terms of the water consumption and the highest supplies to the groundwater resources (the average ETA sum of 379 mm for both variants in the vegetation period over 7 years, Tables 2 and 3). These variants contained high proportions of grasses, without heliophilous leguminous plants of high transpiration intensity, while soil evaporation was reduced by the permanent presence of the aboveground biomass for major part of the year. Although the nutrients of the NC variant were released from decomposing surface litter and penetrated into the soil profile, they were not utilised for the increase of dry phytomass and the ETA sum due to the late spring regrowth in this variant, and their major portion was leached out (Duffková unpublished). Cernusca *et al.* (1998) also reported that with less intensive management, when the proportion of surface litter on the grassland grows, ETA values drop. Rosset *et al.* (2001) reported almost the same intensity of ETA in the once cut and nocut variants, which consequently resulted in increased soil moisture. PG with minimum management contributes to a higher infiltration capacity of the grassland and to a reduction in the rate of surface water flow because a higher volume of noncapillary pores is maintained due to minimum soil compaction by wheel traffic in comparison with intensively managed grasslands (Hejduk & Kasprzak 2005). This soil microclimate (including lower soil temperatures as a result of shading) also better suits the zooedaphon, which supports the infiltration capacity of soil by loosening (Hejduk & Kasprzak 2004b, 2005). Out of the two variants with reduced evaporation suitable for PZWR, only the 1C vari-

Table 6. Yields of dry phytomass (t/ha) for the entire vegetation period in particular years and variants, Klečaty 2000–2004

Year	Variant			
	1C	2C	MVI	MVII
2000	2.62	2.87	3.48	3.47
2001	2.10	4.80	2.86	2.89
2002	3.52	3.83	2.08	6.77
2003	4.71	2.98	4.15	5.19
2004	5.15	3.52	4.69	5.80
$\bar{x}$ 2000–2004	3.62	3.60	3.45	4.82

ant can be recommended as a management variant because PG cannot be left unused due to the negative impact on the botanical composition (e.g. Grevilliot & Muller 2001; Pykala *et al.* 2005; Kahmen *et al.* 2002) and for aesthetic reasons. The 2C variant containing leguminous plants with high water requirements had the highest water consumption for evaporation (7-year average of 395 mm per vegetation period) and the lowest amount of water runoff from the soil profile. Both mulched variants had approximately the same water consumption (7-year average: MVII 384 mm, 5-year average: MVI 398 mm, MVII 399 mm), higher than the 1C and NC variants. This higher water consumption in mulched variants can be explained by an increased dry phytomass yield as a result of nutrients released from the mulch (Table 6).

CONCLUSION

Differences in the water regime of differently managed grasslands were only observed with sufficient soil water storage (i.e. between field capacity and wilting point). They can manifest themselves in humid years or in conditions with a higher amount of water available for evaporation (heavy-textured soils, higher groundwater level), e.g. in the accumulation zone of PZWR. Once-cut management, which appeared to be the most economical in terms of water consumption, can be recommended mainly in the infiltration zone of PZWR, with prevailing soils of higher infiltration capacity, lighter texture, shallower soil profile, and lower productivity. As the aboveground phytomass is usually less productive compared to e.g. the accumulation zone, the once-cut management does not pose a risk of surface litter accumulation. The cut should be done by ca mid-July. If performed later, the botanical composition of the grassland may be affected negatively due to the suppression of low species, weed infestation, and the reduction of forage digestibility. In the accumulation zone, which is usually situated in floodplains with deep soil profiles, the production of the aboveground phytomass is relatively high, and once-cut management risks to lead to the accumulation of surface litter. Twice-cut management should be applied instead, but no mulching as that would support the yielding capacity of the grassland. Mulching may occasionally represent a relatively suitable treatment for a site with a low yielding capacity in the infiltration area if the demand for bulk feeds is low. The decomposition of a relatively low phytomass volume does not impact negatively the botanical composition of the grassland by suppressing low species damaged by the mulch layer and will moderately enrich the soil profile in nutrients. However, grassland mulching is not suitable in eutrophic sites and in grasslands with a high proportion of clover crops because of the increased risk of nitrate leaching into groundwater.

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