The development of above-ground biomass in unmanaged grasslands and its influence on the leakage of water and the amount of elements found

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ABSTRACT

The influence of various forms of farming on unmanaged grasslands was monitored with regard to the accumulation of the above-ground biomass (litter + mulching) and its influence on the leakage of rainfall and the amount of elements in lysimetric waters. In 2001–2005, the highest accumulation was observed in variants 1× mulched in the later term and on green fallow (on average 2.11–1.13 t of dry matter/ha). In comparison with the control site, a conclusive increase always occurred. An interannual increase of dry matter amounted to 0.4–5.2% of the total above-ground biomass. A negative correlative dependency on rainfall leakage on this material was discovered; at a depth of 0.4 m 4–10% of the rainfall leaked, but it had a significant influence on the wash out of Ca, Mg and S. The leakage of water affected a wash out of N_{min}, P, K, Ca, Mg and S more than the weight of dry matter of the above-ground biomass. With the exception of P, the elements showed a downward tendency over five years. The above-mentioned forms of farming annually increased the accumulation of the above-ground biomass by 0.05–0.16 t of dry matter/ha; however, they do not endanger underground waters by washing out minerals. After a five-year period, a disturbance of the ecological stability of grassland did not occur.

Keywords: unmanaged grasslands; accumulation of above-ground biomass; lysimetric water; nutrients

Cultural grasslands and landscapes need some additional maintenance energy and need to be adjusted to farming. The area of grasslands not used for foraging is estimated to be one third of the total area of meadows and pastures. Most likely, it will not be possible or profitable for farmers to remove grass matter that they will not need for other uses and purposes. Until the return of cattle on these plots of land, the maintenance necessary for the upkeep of extra-production functions, i.e. protection of water, soil and conservation of biodiversity, is needed. For this it is necessary to determine modified pratotechnics to maintain the ecological stability of the grasslands and the environment. The purpose is then to ensure that the compiled biomass does not significantly disturb the structure of the land and the leakage of rainfall and that its subsequent decomposition does not endanger underground waters.

The relationship between the accumulated dead biomass on unmanaged grasslands and pure nutrients in lysimetric waters has not been sufficiently documented so far. The majority of values were measured in deeper depths to express the extent of wash out, i.e. the exploiting of nutrients by plants (Dressel 1992, Hösch and Dersch 2003). In grasslands, the most active zone is in soil up to 0.4 m where 94% of root matter is located (Sobotik 1992). It is exactly at this depth that lysimeters were put because it shows the boundary between active root zone and the loss of nutrients by wash out. The wash out of nutrients and its dependence on fertilization was initially studied in arable land (Borin et al. 2003). On unmanaged grasslands, the documentation is more focused on the influence of various farming methods on the botanical representation (Gaisler et al. 2004, Svobodová and Šantrůček 2004). The correlation between organic

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matter in soil and its influence on soil properties was investigated thoroughly. The dependencies of the content of nitrogen on carbon as well as the loss of nutrients by wash out are well known (Kubát et al. 1999, Vaněk et al. 1999, 2003, Behrendt et al. 2003, Rupp et al. 2003); at the same time, the surface of grasslands was studied only with regard to fertilization – slurry, manure, compost. Actual residual grass matter effect became evident after ploughing. Particularly after winter, the influence of previous agrotechnics was obvious in the wash out of nitrates. Areas mulched in the past demonstrated a significantly higher concentration of nitrates in lysimetric waters (on average more than 2×) than areas also cut but with the removal of the material (Svobodová and Šantrůček 2004).

We proceeded with the hypothesis that the disturbance of the ecological stability of grasslands not used for forage is caused mainly by a high accumulation of grass biomass followed by a change of botanical composition. The consequence is then worsening of the quality of underground water. The objective of this project was to find out the interannual increase of dead plant biomass and its influence on the amount of N_{min} and basic macroelements in lysimetric waters.

MATERIAL AND METHODS

This experiment was conducted from 2001 to 2005 in the foothills of the Jizerské Mountains at 420 m above sea level. The field trial was in acid cambisol pH (KCl) 5.0, C_{ox} 3.62%, N_t 0.32%, P 16, K 106, Mg 64 mg/kg with unmanaged grasslands with a majority of red fescue, association *Trifolio-Festucetum rubrae*, Oberdorfer 1957, and 12% clover crops. Growths were not fertilized. In order to express interannual differences, every year at the end of October, residual above-ground biomass (mulch + litter) was removed from 4 areas 0.20 × 0.20 m with one replication per each area. Dry matter and the calculation of weight per ha were quantified from removed samples.

Lysimetric water samples were analyzed for quantity measurement and an analysis of NO_3^-, NH_4^+, P, K, Ca, Mg and S by continuous-flow colorimeter SAN and plus-Skalar were carried out 4–5× annually (even in winter).

Setting the experiment: the experiment had 10 variants in four replications, the size of each plot was 37 m^2, each variant was done in four replications and had a lysimeter at a depth of 0.4 m in an area of 0.1 m^2.

(1) control (2× cutting, 30.5.–10.6. and 10.8.–20.8., material removed)
(2) green fallow (left without cutting)
(3) rotation of fallow with mulching (1st year fallow, 2nd year mulching 2× 30.5.–10.6. and 10.–20.8.)
(4) rotation of fallow with harvest (1st year fallow, 2nd year 1× cut 15.7., material removed)
(5) rotation of mulching with harvest (1st year mulching 2×, 2nd year 1× cutting 15.7., material removed)
(6) mulching 1× (25.5., material left)
(7) mulching 1× (15.7., material left)
(8) mulching 1× (25.9., material left)
(9) mulching 2× (30.5.–10.6. and 10.8.–20.8., material left)
(10) mulching 3× (25.5., 15.7., 25.9., material left)

RESULTS AND DISCUSSION

The influence of various methods of farming resulted in different amounts of above-ground biomass which remained at sites and accumulated itself (Figure 1); the properly farmed variant with material removed (economic yield) at the time of cutting had the least amount of it – on average 0.17 t of dry matter/ha, variants 8 and 9 mulched 1× at later terms (2.11.) – 1.14 t/ha and green fallow – 1.13 t/ha had the most of it. However, a statistically significant difference in comparison with variant 1 – properly farmed (P < 0.05) was found at all variants. Compared to all other forms of farming than those done properly with the material removed, the above-ground biomass stayed in a noticeably greater quantity. During the period of monitoring, the accumulation of biomass had an increased tendency at all variants, with the exception of 5 (the rotation of mulching with harvest). At a properly farmed variant, the accumulation of above-ground biomass increased only very little and therefore insignificantly. An interannual increase of dry matter here was 0.01 t/ha, i.e. 0.4% from the overall above-ground biomass including stubble. At variant 1× mulched in May, the interannual increase was 0.07 t/ha (1.6%), at variant 2× mulched – 0.04 t/ha (1.2%), at variant 3× mulched – 0.16 t/ha (5.2%), at variant left as green fallow – 0.14 t/ha (2.1%) (Figure 2). Rychnovská et al. (1987) discovered that from the results of a dynamic study of the amount, production and decomposition of above-ground plant litter of grassland, an average of 1.42 t of dry litter/ha is produced during vegetation. The interannual increase of litter of unmanaged grassland was 1.5% (Dykyjová et al. 1989).

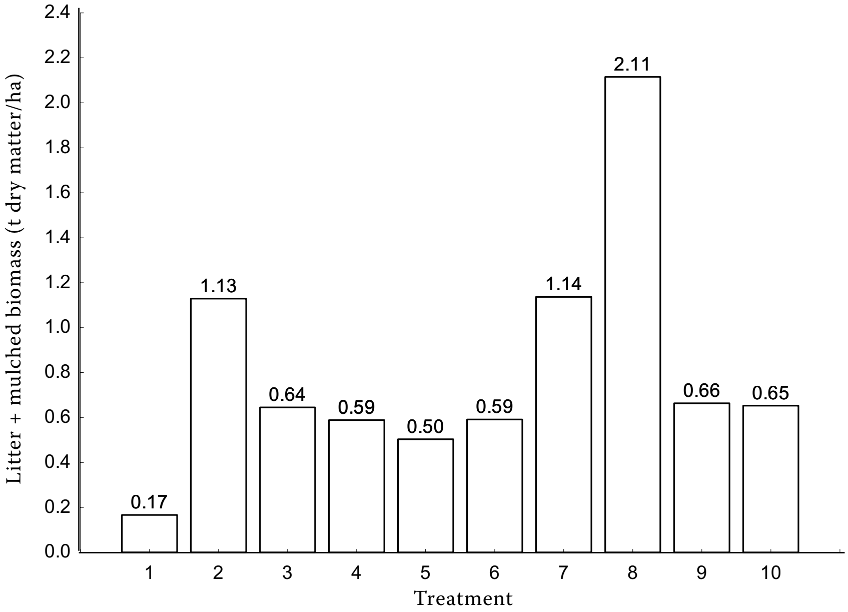

Figure 1. Accumulation of above-ground dead plant biomass (average 2001–2005)

The influence of accumulated biomass on the leakage of rainfall is shown in Figure 3. An indirect correlative dependency can be found here ($r = -0.185$). A statistically significant difference in comparison with variant 1 – properly farmed, was at variant 2 – left fallow, 4 – rotation of fallow with harvest and 6–8, i.e. 1× mulching in three different terms. The majority of rainfall, as measured at a depth of 0.4 m, leaked most at harvest with material removed (10% of the an-

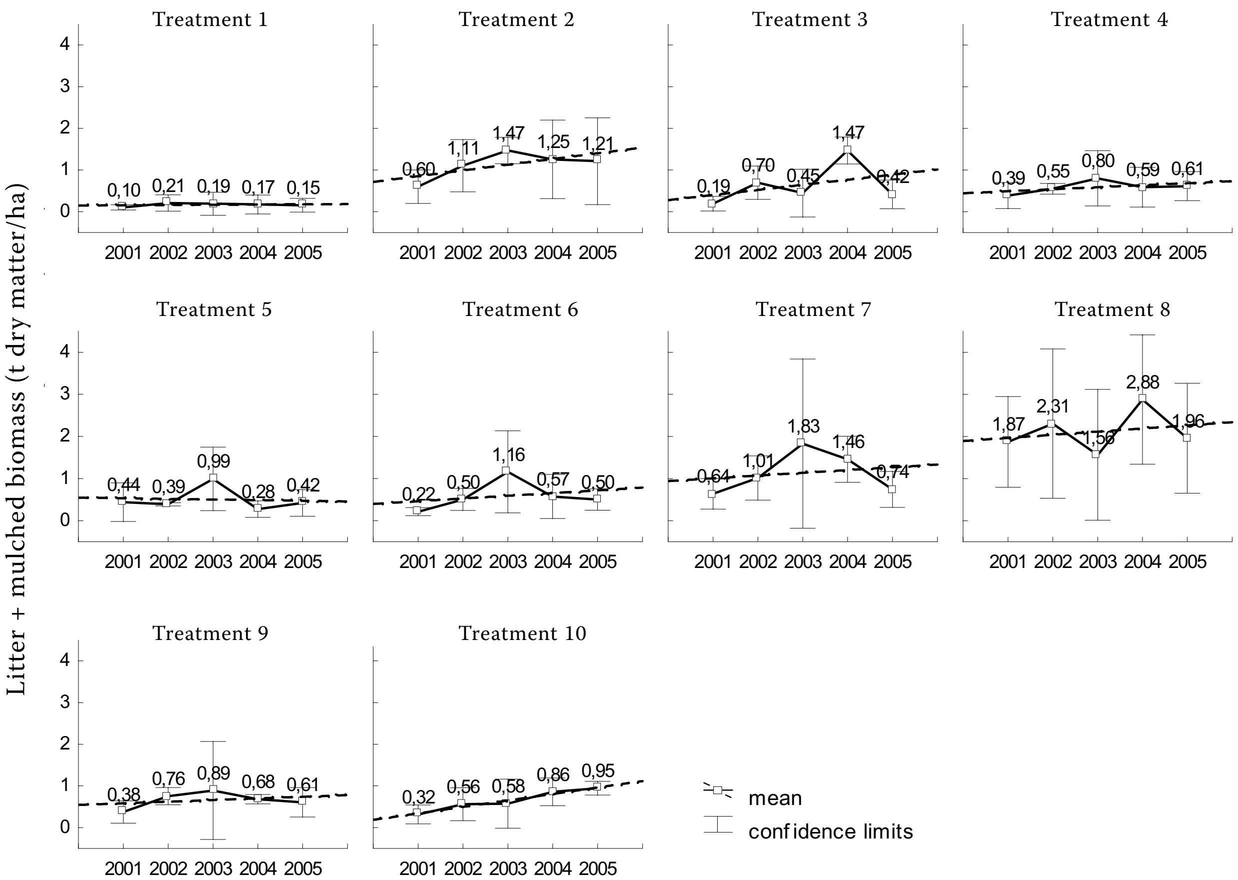

Figure 2. Development of the accumulation of above-ground dead plant biomass

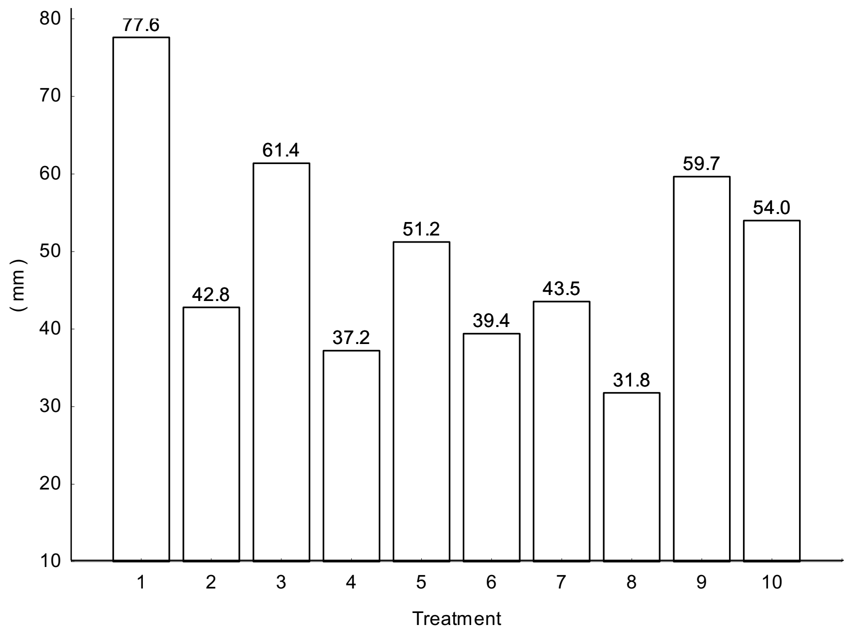

Figure 3. Leakage of rainfall at a depth of 0.4 m per annum (average 2001–2005)

nual total) and the least at 1× mulching in the late term (4%).

In the evaluation of the influence of dead above-ground biomass on mineral nitrogen and elements, we take into consideration their amounts in percolates calculated per ha at a depth of 0.4 m. Figure 4 shows the amount and tendency of mineral nitrogen. As an average of the monitored years, the most mineral nitrogen was at variant 3 – rotation of fallow with mulching 2.40 kg/ha and the least in

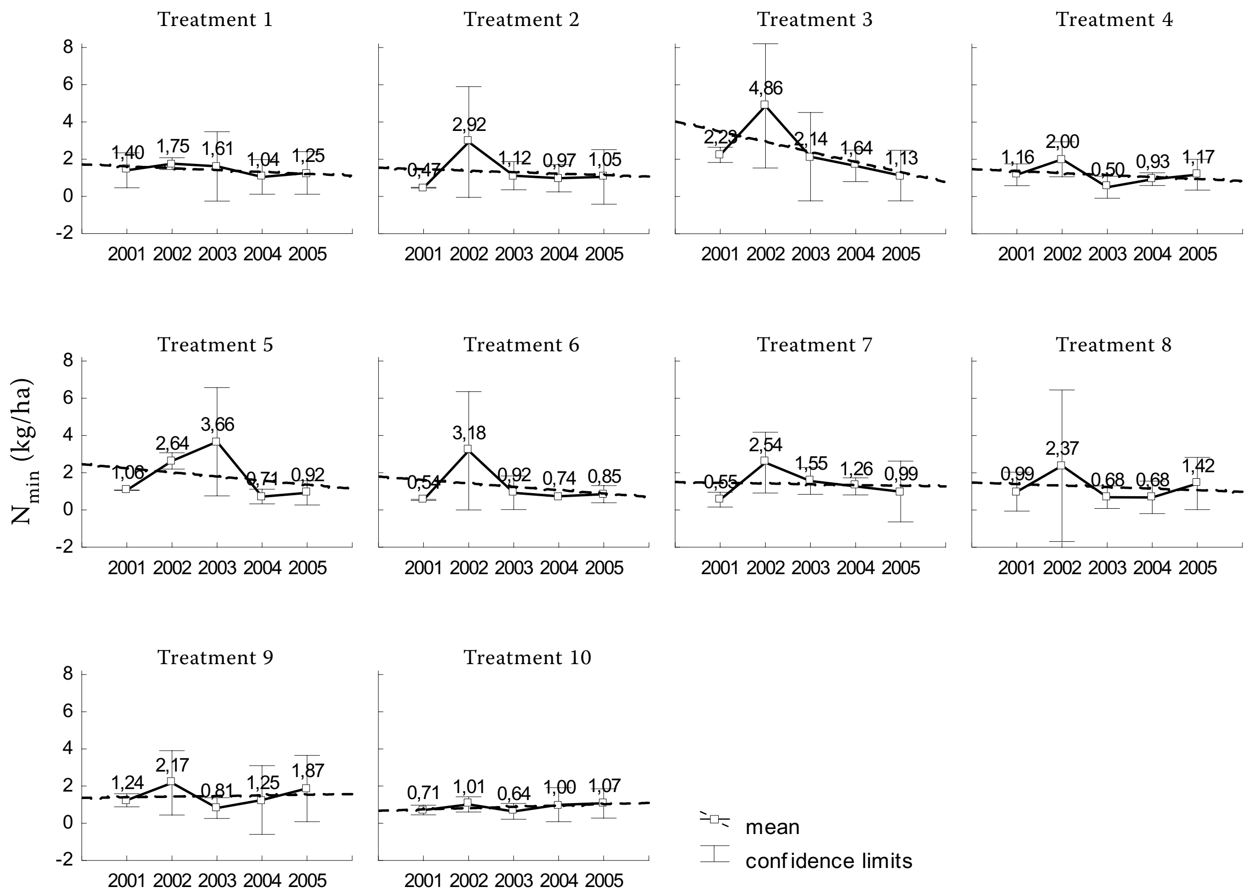

Figure 4. Amount of mineral N at a depth of 0.4 m

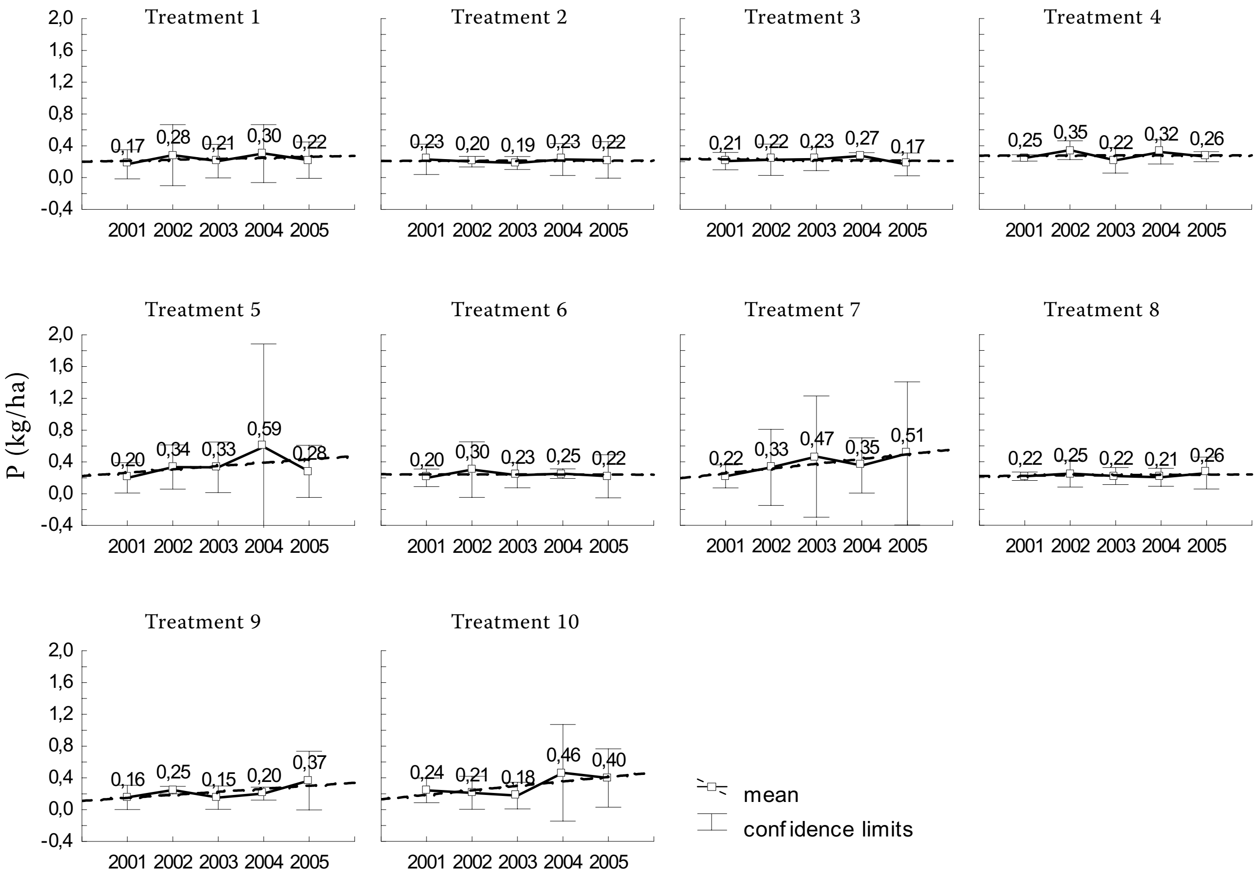

Figure 5. Amount of P at a depth of 0.4 m

variant 10 – 3× mulched 0.89 kg/ha. A statistically significant difference (at $P < 0.05$) in comparison with the control was only at variant 3 with a maximum amount of mineral nitrogen. In the course of the monitored years, nitrogen stayed at the same level, or only slightly decreased, with the exception of variant 2× and 3× mulched. A correlative dependency of N_{min} in a depth of 0.4 m on the weight of the above-ground biomass was positive but very low ($r = 0.006$, at $P < 0.05$). The leakage of rainfall had far a bigger influence on the amount of N_{min} in the lysimetric waters; the correlation here is $r = 0.186$, whereas Kopec (1993) discovered 5–6 kg of N in unmanaged cambisol grasslands. Organic fertilization increases the content of organic carbon in soil as well as the amount of bacteria; however, it does not influence mineralization speed until there is certain equilibrium between input and decomposition (Kubát et al. 1999). Behrendt et al. (2003) determined a correlation between organic substance and the content of nitrogen in soil under a pasture; there is a linear increase in the content of nitrogen with a growing content of organic matter, and carbon arises from this. If we take into consideration that in the above-ground biomass of unmanaged grassland there is 57–100 kg of N/ha fixed (Úlehlová 1989, Fiala and Tichý 1994), then after an intrinsic mineralization of this matter only a small amount infiltrates and thus does not endanger underground waters.

The amount of P in lysimetric waters at a depth of 0.4 m, in comparison with N_{min}, increased in all forms of farming (Figure 5). The average annual increase was only 0.05 kg of P/ha, which is, however, 25% more than the original amount. There were no statistically significant differences in comparison with the control here. On average, at a depth of 0.4 m 0.26 kg of P/ha was measured. This value differs significantly from those assessed by Kopec (1993), but it is equivalent to the values in lysimetric waters under unmanaged grasslands in cambisol (Eder 1991). The dependency of the amount of P on above-ground biomass is positive but low ($r = 0.022$, at $P < 0.05$).

Average potassium infiltrated at a depth of 0.4 m was 2.90 kg/ha, whereas Kopec (1995) measured 5.00 kg/ha. Among the variants and the farming methods there was not a significant difference. The correlative dependency of K on the amount of biomass was very low but still positive ($r = 0.059$, at $P < 0.05$). The tendency was descending, with

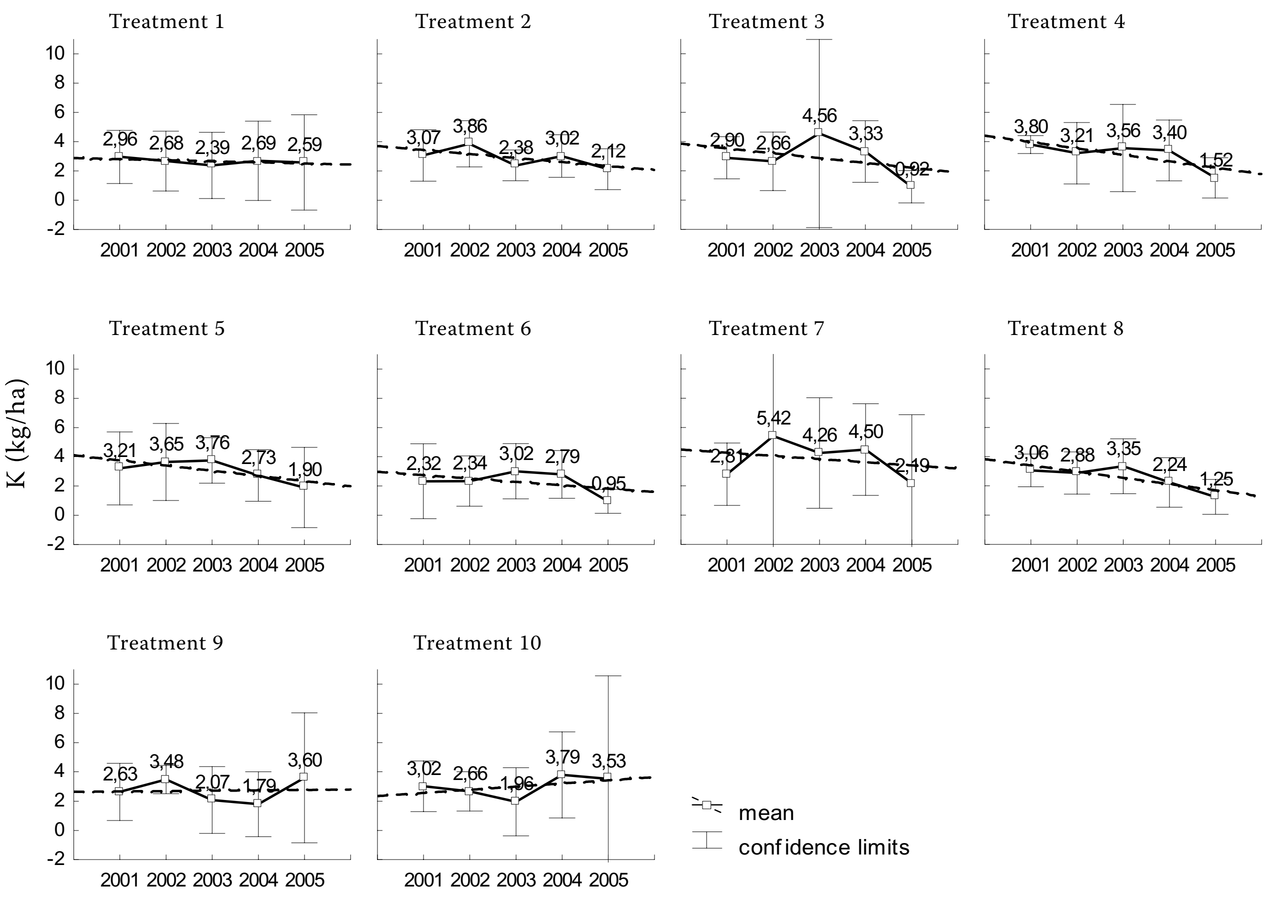

Figure 6. Amount of K at a depth of 0.4 m

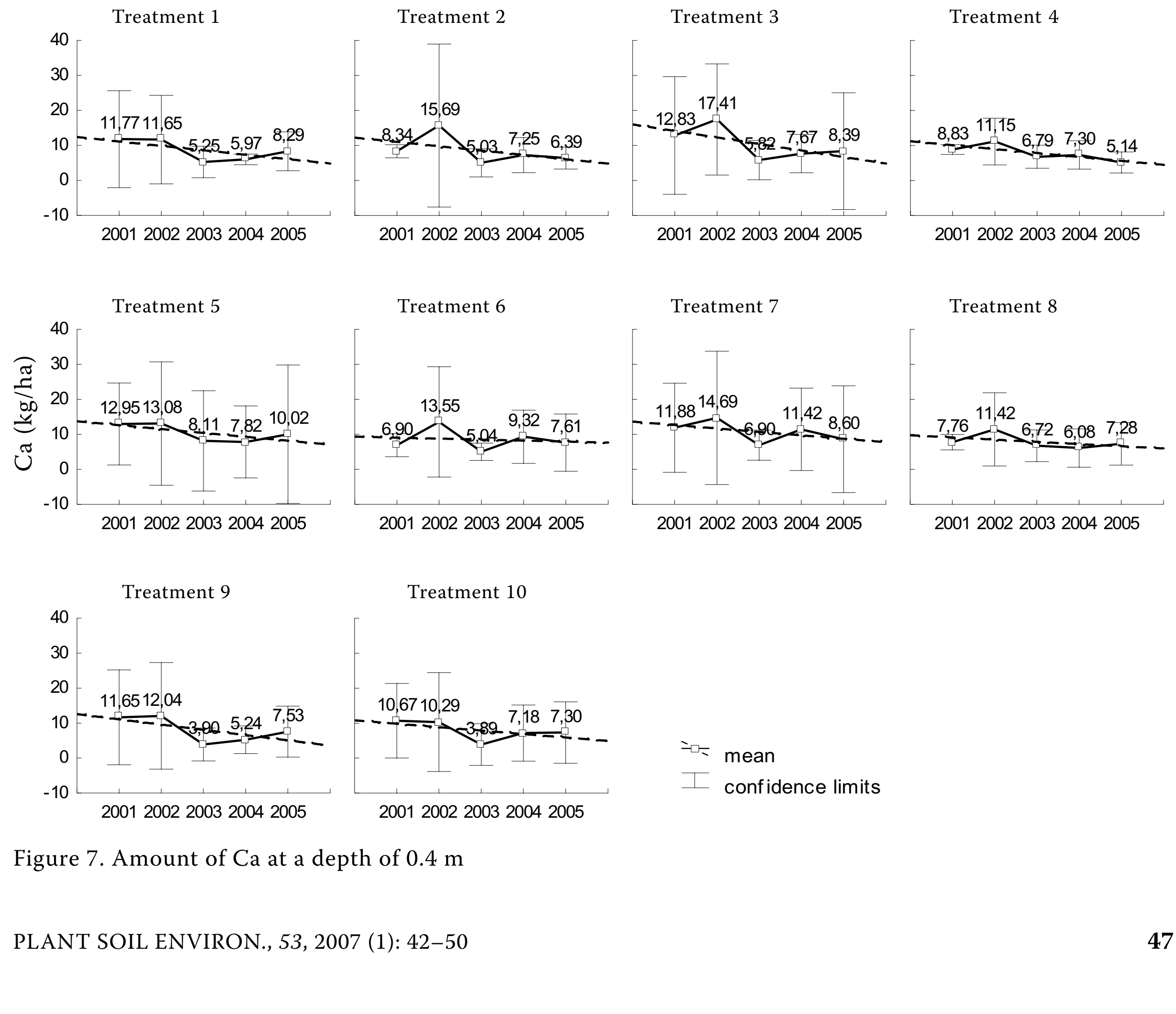

Figure 7. Amount of Ca at a depth of 0.4 m

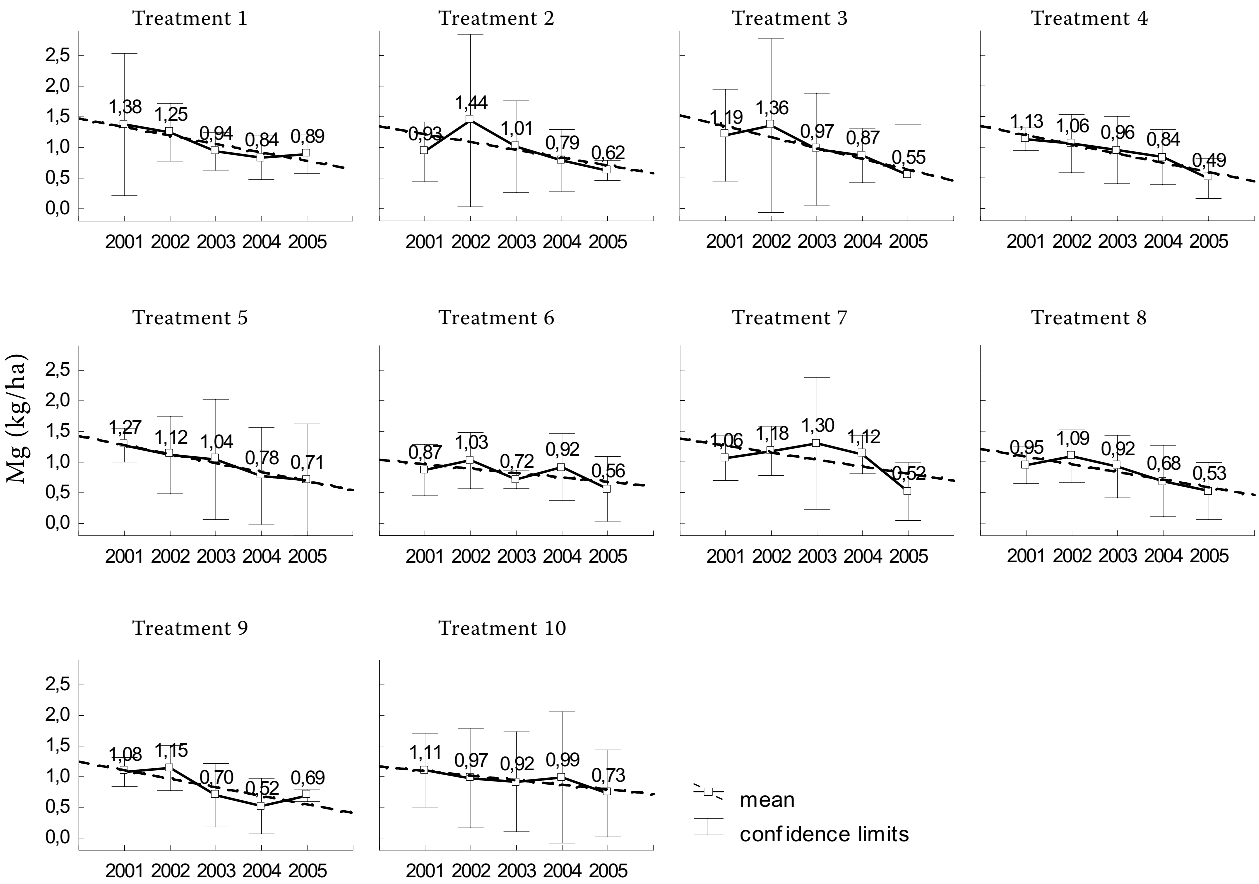

Figure 8. Amount of Mg at a depth of 0.4 m

the exception of mulching 2× and 3×, as well as at N_{min} (Figure 6).

In a 5-year average, calcium was measured in lysimetric waters at 8.90 kg/ha. Kopec (1993) measured 120.00 kg at the depth of 1 m; Mareš and Královec (2003) measured the decline of material at 9.60 and at green fallow at 6.70 kg/ha. The amount of Ca had a descending tendency during monitoring of all the variants; there was not a statistically significant difference among them. The correlative dependency on the amount of above-ground biomass was very low and negative (r = –0.018). However, the dependency on the amount of leaked rainfall was relatively strong r = 0.416, at $P < 0.05$ (Figure 7).

Average magnesium washed out at a depth of 0.4 m was 0.93 kg/ha. There was not a statistically significant difference among variants here, either. The correlative dependency on the amount of Mg on the accumulation of the above-ground biomass was slightly negative (r = –0.073). Here, as with the calcium, a significant dependency on the leakage of water was discovered (r = 0.422). This is why these two elements should be supplied by fertilization in grassland areas used for foraging (Figure 8).

The amount of sulphur had a descending tendency similarly to magnesium. On average, 2.45 kg/ha washed out. There was no statistically significant difference. The correlative dependency on the above-ground biomass was weak and negative (r = –0.088). However, the dependency on the amount of washed out rainfall was the strongest of all monitored elements r = 0.590, at $P < 0.05$ (Figure 9).

The significance of the determined results is based primarily on the possibilities for the specification of the definition of "Environmental criteria of the disturbance of the ecological stability of grasslands" and, for general practice, they may be used in the determination of the grant policy of the state for unmanaged grasslands. Criteria present for the disturbance of stability are based on the accumulation of grass biomass, botanical composition and the quality of underground water (Fiala 2004). However, it is necessary henceforth to determine the critical amount of accumulated biomass. With any technology or pratotechnics

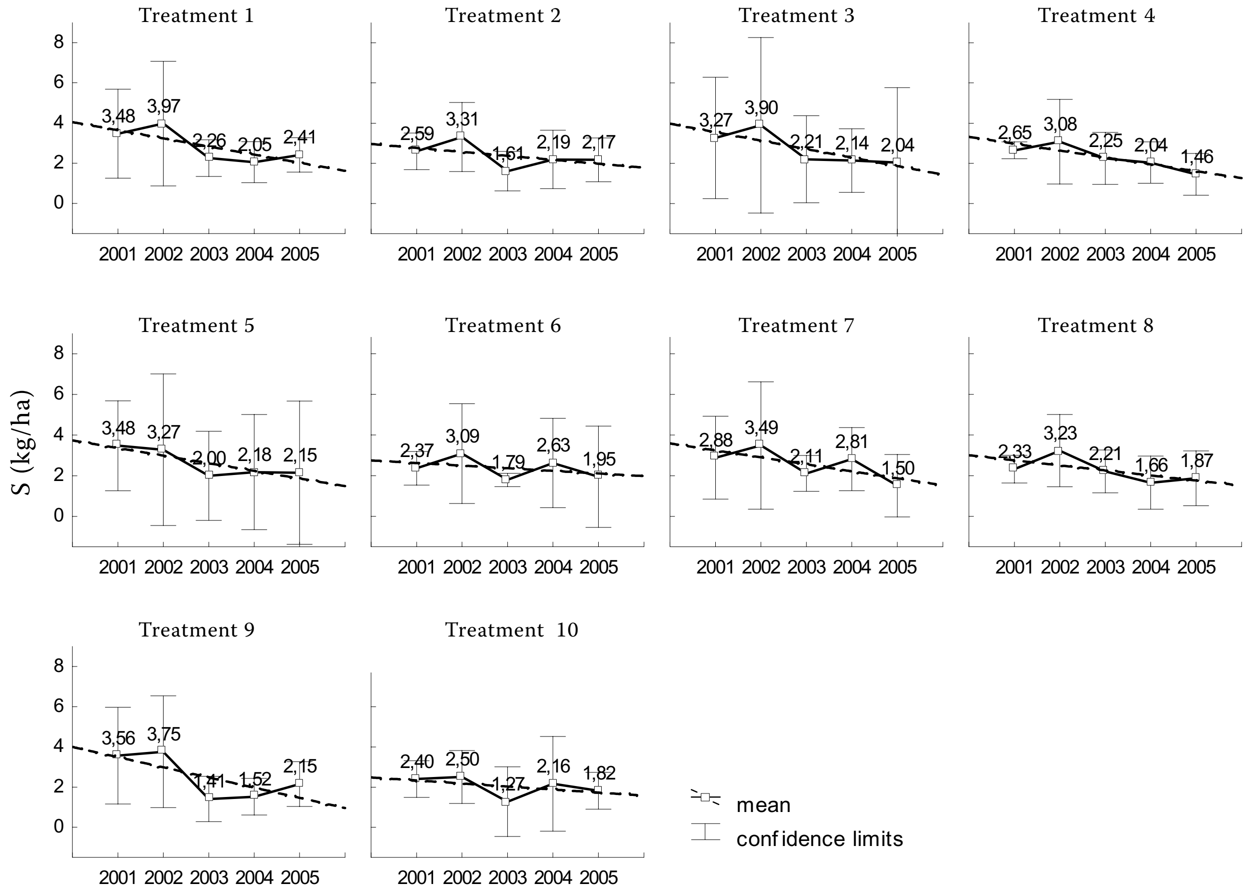

Figure 9. Amount of S at a depth of 0.4 m

it may be reached and have consequences, i.e. the change of critical amount of NO_3^- in water. Logically, this will require a longer period of monitoring.

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