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Amounts of throughfall and lysimetric water in a sub-mountain beech forest in the Kremnické vrchy Mts. (West Carpathian Mts., Slovakia)

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ABSTRACT: The paper deals with throughfall and soil percolation in a sub-mountain beech forest situated at the Ecological Experimental Site (EES) Kremnické vrchy Mts. (the West Carpathian Mts., Slovakia). The research was conducted in 1988–2008. The throughfall was sampled at regular periods, both from the open plot (clear-cut) and from the plot with complete stocking, covered with a mature beech stand. The soil percolation was evaluated with soil lysimeters. In 1989 and 2004, the plots were treated with cutting – with the aim to reduce the current stocking. The average amount of throughfall was 772.2 mm in the open plot and 616.3 mm in the control. The amount of soil percolation decreased with increasing depth: from 398.9 mm to 103.8 mm in the control and from 488.8 mm (surface) through 169.9 mm (10 cm) to 188.8 mm (25 cm) in the open plot. The differences between the plots were statistically highly significant. No significant differences were found between the soil horizons.

Keywords: throughfall; lysimeter; sub-mountain beech forest; water balance

Water as a substantial component of the living environment is a limiting factor for plants, animals and humans themselves. The amount of (surface and ground) water significantly influences, both in a positive and negative way, the processes of biomass production in individual constituents of all ecosystems, and the life itself in this way. At present, at the first place, commercial aspects of this fact are reaching the top of the agenda. The potential reserves of "suitable" water are continually decreasing, mainly due to negative human activities. Thriftless exploitation of this precious natural resource can result in an enormous effort required for its restoration in the future.

It is evident that the functioning of the individual ecosystems must be understood in the context of their interactions. Nothing in the living environment operates separately. The individual components are subjected to parallel effects of several factors. It is very probable that the thorough understanding and correct interpretation of all the grounds will never be reached. The aim of our work was to provide a small contribution to the discussion about the performance of some processes running within such complicated systems as the living environment.

The crucial importance of the issue is also evident from the number of authors dealing with it in the recent past (Faško, Lapin 1994; Matzner, Meivess 1994; Pichler 1996; Dubová 1996). Today, everything linked with water is mainly put in connection with a possible climate change, its negative impact at the first place. It is of cardinal importance to subject this problem to progressive serious research, following the suit of Kantor (1984b), Lapin (1988), Gregor and Tužinský (1999), Širáň (2003).

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MATERIAL AND METHODS

We monitored throughfall and soil solutions (Kukla 2002) in beech stands at the Ecological Experimental Site Kremnické vrchy Mts., using the methods elaborated by Dubová (1996). In general, we measured the throughfall amounts after each precipitation event. The water was collected into vessels with precisely specified interception surface. Ten vessels were placed on the plot with planned and accomplished clear-cutting, the other ten vessels were situated on the control plot. The collection and processing of throughfall water were carried out according to Kukla (2002). At four-week intervals, we also took totals of gravitational water from the soil depths of 0.10 and 25 cm, also on both plots. The research plots are situated in the Kremnické vrchy Mts. (48°38'N and 19°04'E) belonging to the area of the West Carpathian Mts. The species composition is dominated by beech, the stand age is 80–110 years.

In terms of climate, the plots are situated in moderately warm, moderately mountainous B5 District, with the mean annual temperature $t_{1951–1980}$ –6.8°C and mean annual precipitation total 778 mm – Střelec (1993). A more detailed description of the plots can be found in the papers of Janík (2005), Schieber (2006) and Kellerová (2006). The soil description can be found in Kukla (2002) and Širáň (2003). The thorough study in the beech stands at the site Kremnické vrchy sought the optimum intensity of cutting intervention aimed at the reduction of current stocking (Barna 2004). Five partial plots with graded stocking were created, and appropriately timed shelterwood cuttings were applied with the aim to reach the required stand density. Up to the present, two cutting interventions have been accomplished: in 1989 and in 2004. The measured values were evaluated and processed using the Statistica software.

RESULTS AND DISCUSSION

The results summarized in Table 1 show some distinct differences in the precipitation activity between

Table 1. Amounts of lysimetric percolation and precipitation depth (in mm)

Partial plots	Control plot (stocking 0.9)				Clear felling (stocking 0.0)			
	throughfall	Oo-surface humus	0–10 cm	0–25 cm	throughfall	Oo-surface humus	0–10 cm	0–25 cm
Vegetation period	264.4	291.1	142.0	55.0	250.0	70.1	70.1	67.0
Year 1988	479.2	499.1	254.4	170.5	457.1	562.9	196.4	222.7
Vegetation period	209.4	180.0	33.7	15.7	300.5	191.3	68.3	91.8
Year 1989	403.2	296.4	99.8	58.3	541.0	346.4	150.0	170.8
Vegetation period	257.6	286.3	80.7	48.6	405.7	254.9	114.9	175.6
Year 1990	480.6	524.1	198.0	144.2	714.4	559.3	249.2	376.2
Vegetation period	231.2	179.3	48.6	34.8	364.9	240.6	85.8	130.9
Year 1991	513.5	373.7	146.5	109.3	754.5	503.5	186.7	269.2
Vegetation period	138.1	165.7	69.3	26.7	204.0	294.8	29.7	64.0
Year 2003	488.9	262.7	107.0	33.1	636.7	396.8	99.2	137.6
Vegetation period	377.9	200.4	65.8	41.0	204.0	413.8	100.1	20.3
Year 2004	700.8	398.0	211.2	122.4	663.5	608.7	222.4	79.9
Vegetation period	497.9	264.0	83.5	10.6	518.4	294.1	9.7	132.0
Year 2005	720.6	421.0	142.9	131.6	759.4	463.7	135.2	150.1
Vegetation period	757.6	228.0	38.6	14.8	1,050.0	270.8	47.5	81.4
Year 2006	912.1	416.9	106.7	66.5	1,225.5	468.7	120.5	103.6

the two periods. For the period of the first cutting, only little significant differences were found in the values observed on the same plot before and after the intervention. This fact probably resulted from the lack of precipitation activity after the treatment – see Dubová (1996). This lady-author evaluated the years after the treatment as extremely dry – below the long-term normal. On the other hand, the period of the second intervention has significantly corroborated our original hypothesis about the influence of forest management on the water-regulating function of forest stands.

The situation in the case of soil solutions seems to be somewhat different because the differences between the depths were not found distinctly statistically significant (*t*-characteristic 0.1–2.1 on the plot K and 0.1–1.6 on the plot H, $\alpha = 0.05$). The objective effect of dry weather after the treatment was coupled with the not less important effect of herbal synusia in the understorey, density of plant roots in the soil cover varying with the depth (Mitscherlich 1978), physical and mechanical properties of soil, slope gradient and many other factors. This fact was also confirmed by Kantor (1995), who observed little significant differences in soil drying between the soil in an adult beech stand and the soil on a weeded open plot. Pichler (1996), in contrast, explained opposite results obtained in his research as caused by lower interception losses in the range of medium-high mountains where he carried out his research.

The courses of total amounts of soil percolation on the control plot without intervention and on the plot subjected to clear-cutting were different. The amount of water in the soil under the totally closed parent stand decreased with depth over the whole study period. On average, of the total amount of gravitational water from the soil surface only 65.6% reached the depth of 10 cm and only 26.2% percolated into the depth of 25 cm. In the opened plot, the values were found to fluctuate, in most cases the water amount was however higher at the depth of 25 cm than at the depth of 10 cm. Similar results were obtained by Širáň (2003), who evaluated the soil without forest stand as moister from the aspect the whole soil profile. Intribus (1966) examined beech stands thinned from above, and he found that in a moderately dry period, the more favourable moisture conditions were under the stand. Pichler (1996) suggested that important precipitation is the precipitation enabling larger water amounts to percolate into deeper soil layers.

The statistical evaluation has resulted in a finding that only 54–71% of the amount of water fallen on the plot without stand cover reached the soil under the parent stand. Dubová (1996), reports in this context a value of 70% on average. The testing confirmed a high level of significance of differences between the two studied plots (*t*-characteristic 3.3–3.8 is highly significant at $\alpha = 0.05$). The influence of the cutting intervention on the water regime of plots was found less pronounced mainly in 1989 – probably due to the absorption effect of the herbal synusia in the understorey and due to the presence of plant roots in soil layers (Tužinský 1984; Papritz et al. 1991).

To evaluate the water balance of the examined forest stands, stemflow is an important factor – as already pointed out by Kantor (1984a), who reported that in the growing season up to 19.9% of precipitation water flows down the beech stems to the ground – compared to the open plot. Kantor

Table 2. Descriptive statistics of throughfall and lysimetric percolation (valid = 8)

	Plots							
	Water K	K_{00}	K_{10}	K_{25}	Water H	H_{00}	H_{10}	H_{25}
Median	501.2	407.5	144.7	115.9	688.9	486.1	168.4	150.1
Sum	469.9	3,191.9	1,266.5	830.4	5,752.1	3,909.9	1,359.6	1,437.4
Min	403.2	262.7	99.8	33.1	457.1	346.4	99.2	79.9
Max	912.1	524.1	254.4	170.5	1,225.5	608.7	249.2	376.2
Range	508.9	261.4	154.6	137.4	768.4	262.3	150.0	296.3
Variance	29,748.4	8,031.8	3,243.2	2,202.1	52,797.9	7,834.1	2,724.0	942.7
Std. dev.	172.5	89.6	56.9	46.9	229.8	88.5	52.9	97.1
Vx%	29.4	22.5	35.9	45.1	31.9	18.1	31.1	54.0
Mean	587.4	398.9	158.3	103.8	719.0	488.9	169.9	179.7

Water – throughfall, $K(_{00,10,25})$ – control plot, $H(_{00,10,25})$ – clear felling and Šach (2008) measured up to 1,500 l of water flown down a beech stem at a 50 mm precipitation event. Similar results were also obtained by Minďáš et al. (2001).

Statistical evaluation of the measured totals is summarized in Table 2.

CONCLUSION

In summary, in our research performed in the years 1988–1991 and 2003–2006 we obtained an average value of 616.3 mm (79.8%) for throughfall on the open plot and 772.2 mm for throughfall on the clear-cut. The total amounts of soil percolation decreased with depth, reaching the values of 398.9 mm, 158.3 mm and 103.8 mm on the totally closed plot and the corresponding values of 488.8 mm, 169.9 mm and 188.8 mm on the deforested plot. The pair testing supported the hypothesis about an important impact of management intervention (reduction of stocking) on the water balance of studied plots (*t*-characteristic 2.3–4.1 statistically highly significant by $\alpha = 0.05$). This influence manifested in the individual soil horizons was less conspicuous.

Research oriented in this way cannot however omit the physiological processes running in interaction with plants, soil, and water balance – which was already pointed out by Papritz et al. (1991) and Flückiger and Braun et al. (1992). The differences in the soil water balance between the studied plots with full stocking and without forest cover confirm the importance of the purposeful control of natural processes taking place in forest ecosystems. Today, this is mostly connected with the presence of extreme weather situations, primarily those associated with floods. Kantor (1995) defined dischargeable water as the water that was not either evaporated or transpired. In this context, primarily on slopes, the forest cover with optimum stand closure can very remarkably improve the situation in both surface and sub-surface discharge.

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Množstvo podkorunových zrážok a lyzimetrickej vody v podhorských bukových porastoch Kremnických vrchov (Západné Karpaty, Slovensko)

ABSTRAKT: V podmienkach podhorských bučín Ekologického stacionára Kremnické vrchy (Západné Karpaty, Slovensko) sa v rokoch 1988–2008 uskutočňoval výskum podkorunových zrážok a pôdneho priesaku. Podkorunové zrážky sme odoberali v pravidelných časových intervaloch z plochy bez porastu (holina) a z plochy s plným zakmenením, ktorú tvoril dospelý bukový porast. Pôdny priesak bol vyhodnocovaný z pôdnych lyzimetrov. V r. 1989 a 2004 bol na uvedených plochách uskutočnený hospodársky zásah s cieľom redukovať zakmenenie. Na holinu sa v priemere dostalo 772,2 mm a na kontrólnu plochu 616,3 mm podkorunových zrážok. Množstvo pôdneho priesaku na kontrole s hĺbkou klesá od 398,9 mm do 103,8 mm, na ploche bez porastu bola najvyššia hodnota 488,8 mm na povrchu, 169,9 mm v 10 cm a 188,8 mm v 25 cm pôdy. Rozdiely medzi plochami boli štatisticky veľmi významné. Preukaznosť rozdielov medzi pôdnymi horizontami sa nepotvrdila.

Kľúčové slová: podkorunové zrážky; lyzimeter; podhorská bučina; vodná bilancia

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