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RAINFALL INTERCEPTION IN A FOREST IN THE VELEN HYDROLOGICAL REPRESENTATIVE BASIN

Treatment of data from the summer and autumn of 1973

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In the summer and autumn of 1973, 25 rain troughs were operating below canopy and four in clearings of a predominantly coniferous forest in the Velen hydrological research area. The collected rain water amounts were measured 14 times (about once a week). Using these data and the records from a tipping-bucket rain gauge in a simple model for throughfall, it was found that the overall water storage capacity of the forest canopy was about 2 mm and that the free throughfall coefficient p was about 0.5. Results from 50 photographs taken upward from the troughs indicate a smaller p-value. The time for evaporation of the intercepted water after an average rain storm is roughly estimated as 5 h. About 26 % of the total rainfall was intercepted and evaporated.

Measurements of evaporation from a forest have been going on since 1970 in an instrument tower in the Velen hydrological research area situated between lakes Vänern and Vättern in southern Sweden. In May 1973, in order to get an idea of the amounts of rain intercepted by the forest, the Institute placed a number of rain troughs below the canopy and in clearings. These give values of rainfall and throughfall. Neglecting stemflow, the difference is the rain intercepted on the canopy.

Table 1.
The numbers of trees counted in 25 squares of 100 m^2 have been averaged and multiplied by 100 to be valid for an area of one hectare

	Height			
	1.5–5 m	5–10 m	> 10 m	Sum
Pinus silvestris (pine)	0	0	404	404
Picea abies (spruce)	424	212	312	948
Betula verrucosa (birch)	24	52	48	124
Sum	448	264	764	1 476

SITE AND INSTRUMENTS

The measurements were made in a flat area of a 60 year old spruce and pine forest. The mean height of the top of the canopy is 22 m and the maximum height is 25 m. In the autumn of 1973 the trees were counted in 25 squares (10 × 10 m) at the rain troughs under the canopy. The result is given in Table 1.

The 25 counts of all trees (corresponding to the sum of 1476 in Table 1) were approximately normally distributed and the standard deviation of the 25 numbers from their mean value was 43 % of the mean. Thus, the standard deviation of the mean is estimated as $43/\sqrt{25} = 9$ %. This gives an idea of the uncertainty of the sum of 1476 trees per ha. (The standard deviation of the mean of a large number of imagined samples is estimated from the size N and the standard-deviation S of *one* sample by $S/\sqrt{N}$, see ISO report of 1973).

To measure rainfall and throughfall, four troughs were placed in two major clearings and 25 troughs below the canopy around the meteorological tower (see Fig. 1). A storage gauge (accumulator) was placed in each clearing. In a small clearing just north of the tower an OTA tipping-bucket gauge (tipping for each 0.5 mm) was recording continuously.

Each trough was 198 cm long, 15 cm wide and 20 cm deep, so the total catchment area below the canopy was approximately 7.5 m^2. To make rain water run out, the troughs slope at about 1:6. The water caught is led down into a container (25 l) through a plastic tube (see Fig. 2). To prevent evaporation of the water collected, the containers were equipped with almost airtight inlets. To see if there was evaporation from the containers, 1000 ml of water was poured into one of them. Then the upper end of the tube was turned

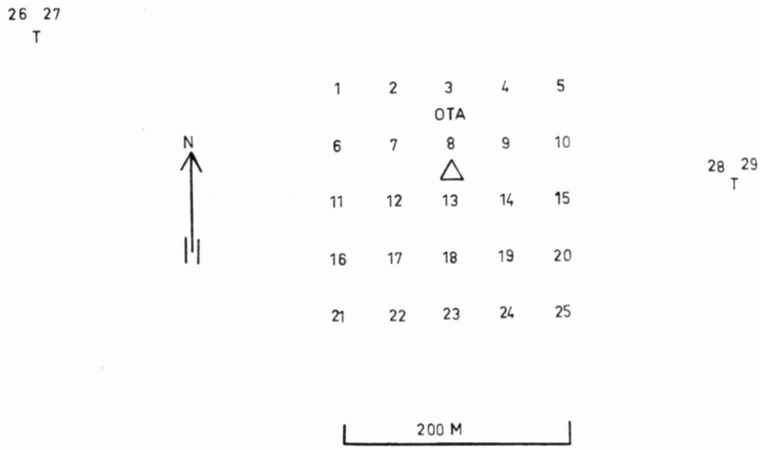


Fig. 1.

Schematic map showing positions of rain gauges and troughs around the Velen tower. Numbers stand for rain troughs: 1–25 are below forest canopy, 26–29 are in clearings 10–15 m in diameter and surrounded by low trees. T = Storage gauge (accumulator), OTA = Rain gauge for continuous recording (in clearing 10–15 m in diameter and surrounded by high trees). △ = Instrument tower (54 m high).

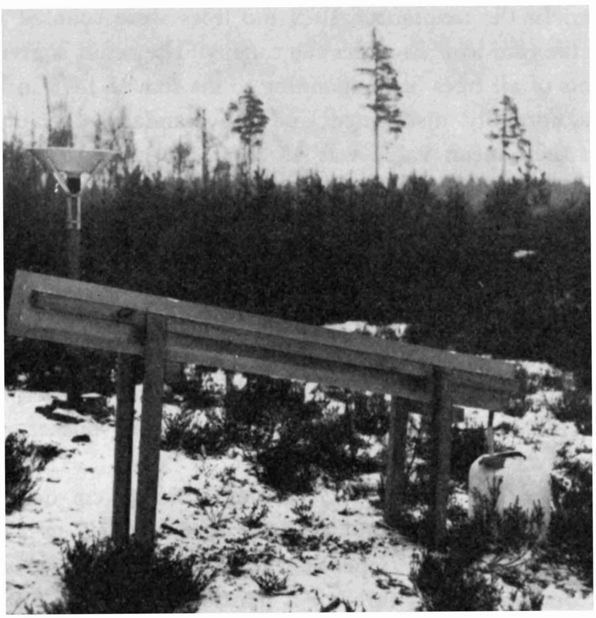


Fig. 2.

One trough and accumulator in one of the clearings. The troughs are oriented north-south.

downwards instead of being attached to the trough. After some weeks the amount of water was the same to within 5 ml. Therefore, evaporation from the containers is considered negligible.

The water quantities measured have been converted to mm by dividing by the trough area projected horizontally.

The accumulators in the two major clearings are known to have very small evaporation losses and are also designed to avoid errors due to wind speed. They have an opening 1.5 m above ground and are surrounded by a conical wind shelter (see Fig. 2). The water is stored in a tube 1–2 m below ground level.

THEORY

Following the principles of a paper on rainfall interception in forests by Rutter et al. (1971), rainfall and throughfall in *one* storm can be described as follows (see also Fig. 3).

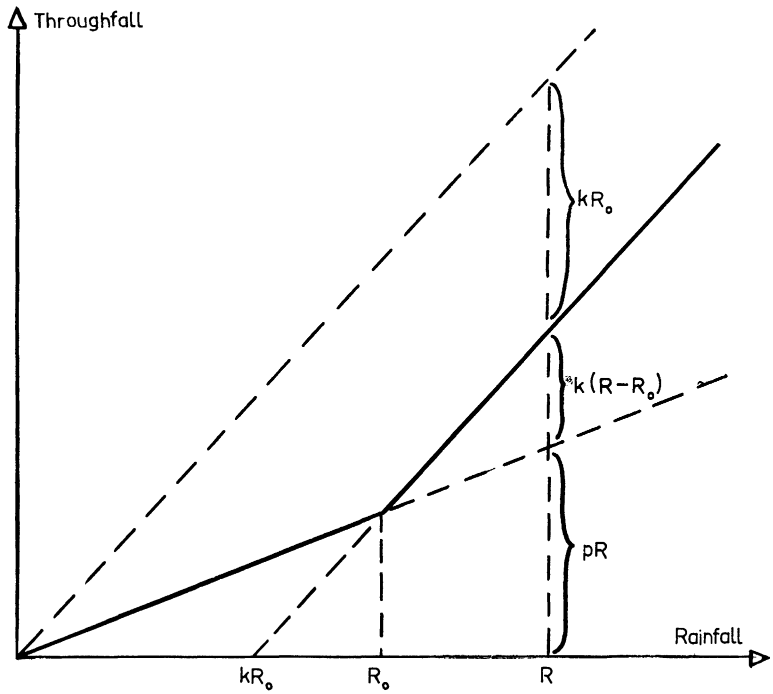


Fig. 3.
The solid line gives throughfall as function of rainfall in *one* storm.

If rainfall R does not exceed a limit R_0 the throughfall T may be written:

$$T = p \cdot R \tag{1}$$

p is the proportion of rain which falls through the canopy without striking a surface and corresponds to the proportion of the sky which can be seen upwards from below the canopy. It is often called the free throughfall coefficient.

If $R \geqq R_0$ the canopy becomes oversaturated and water drains from the canopy during and after the storm.

Then

$$T = pR + k(R-R_0) \tag{2}$$

Since it must be expected that $dT/dR = 1$ we have $p + k = 1$ and

$$T = R-kR_0$$

where kR_0 or S (the symbol to be used in a later section)
is the amount of water (mm) which can be stored on the canopy. This was called the canopy storage capacity by Rutter et al. (1971). This water will evaporate completely after a rainstorm if the dry weather period is long enough. To sum up, the throughfall T is given by

$$R-T = kR \text{ if } R \leqq R_0 \tag{1a}$$

$$R-T \equiv kR_0 \text{ if } R \geqq R_0 \tag{2a}$$

Since p corresponds to the free sky, k corresponds to the tree-mass covered area seen upwards from the ground.

The amount of water required to saturate the canopy is equivalent to a water layer kR_0 mm thick covering the whole area.

The horizontal area "shadowed" by canopy material is k times the total forest area A. The canopy has to carry the stored water amount. This amount is

$$kA \cdot x$$

where x is the thickness of the water layer averaged over the horizontal shadowed area kA only. The total water amount is also, of course, $A \cdot kR_0$ and therefore $x = R_0$.

Thus R_0 is the water layer thickness averaged over the horizontal area shadowed by canopy material.

The value kR_0, which is smaller than R_0, is the thickness averaged over the total horizontal area of forest.

Factors which have been ignored here are:

1) The canopy has no uniquely defined capacity to store intercepted water. In the case of strong winds during or after a rain period the drainage must be larger than in weak winds, as the trees are shaken more intensely.

2) The free throughfall coefficient will decrease when the path of the falling raindrop deviates from the vertical. Some data about this shadowing effect of the trees based on photographs taken upwards from the troughs will be given in a later section.

3) Both p and S show a marked seasonal variation for deciduous forests and there is some variation also in a coniferous forest.

4) The flow of rain water along the tree trunks down to the ground (stemflow) is neglected. This can be expected to be smallest for trees with downward sloping branches which are common in our forest. This quantity has not been measured here. It is estimated by other investigators to be about 1–5 % of the total rainfall. For example, Delfs (1965) found a value of about 1 % averaged over 4 years in a stand of Norway spruce in the Harz Mountains in Germany. Measurements reported by Lawson (1967) in a pine-hardwood stand in the Ouachita Mountains of Arkansas showed that the stemflow was 2.4 % of the average annual gross rainfall.

DATA

The data from the 14 operative periods of the troughs and accumulators are given in Table 2. For each period, the individual readings from the 25 troughs below the canopy are represented by their mean and standard deviation. The OTA tipping-bucket gauge record is represented by the total amount. Additional data from the OTA record will be given in later sections.

To test the troughs, the results from the four troughs in the clearings were compared with data from the two accumulators nearby. The data can be studied in Table 2, and it turns out that the difference:

reading of accumulator minus reading of trough

for the operative periods of Table 2 varied between –0.7 mm and +1.3 mm. There was a weak dependence on the number of drying-up intervals in a period (Table 7): With 1–2 intervals the average difference was zero and with 5–10 intervals it was about 1 mm. Thus, there seem to be some minor evaporation losses in the troughs. The average difference was 0.2 mm.

To determine the amount of water intercepted by the canopy, the difference used was that between troughs in clearings and troughs under the canopy. In this way errors due to differences between types of gauges are thought to have been eliminated.

Table 2.

Observations of rainfall (mm) in clearings and throughfall below canopy around the instrument tower in Velen 1973

Date	Rainfall Accumulators in clearings			Rainfall Troughs in clearings					Throughfall 25 troughs below canopy		Difference: intercepted rain I = R-T	Percentage intercepted rain 100 I/R	Rainfall OTA, tipping bucket gauge in small clearing
	Western 1	Eastern 2	Mean	Western 26	Western 27	Eastern 28	Eastern 29	Mean (R)	Mean (T)	S.d.			
1. 05–17— 21	4.2	4.0	4.1	3.3	3.4	3.3	3.2	3.3	1.7	1.1	1.5	45	2.5
2. 05–21— 22	6.9	5.3	6.1	6.9	7.0	5.6	6.5	6.5	4.5	2.0	2.0	31	5.5
3. 05–22—06–04	24.5	–	24.5	23.4	24.0	22.5	23.0	23.2	14.2	5.5	9.0	39	18.5
4. 06–04— 19	7.3	7.3	7.3	6.7	7.2	7.0	7.2	7.0	4.2	1.8	2.8	40	5.5
5. 06–19—07–19[1]	40.5	32.5	36.5	40.4	40.9	31.5	31.4	36.1	27.1	6.8	9.0	25	35.5
6. 07–19— 26[2]	63.5	61.0	62.3	62.8	66.4	59.5	59.8	62.2	55.0	8.9	7.2	12	63.5
7. 07–26—08–15[2]	58.5	57.0	57.8	50.3	58.4	54.9	55.0	56.5[3]	39.9	13.5	16.6	29	52.5
8. 08–15— 20	11.2	11.2	11.2	10.8	11.6	11.5	11.6	11.6[3]	9.5	2.7	2.1	18	10.5
9. 08–20—09–04	17.3	16.5	16.9	15.2	16.7	15.9	16.1	16.4[3]	11.0	2.9	5.3	33	13.0
10. 09–04— 12	3.2	3.0	3.1	1.9	2.9	2.8	2.8	2.9[3]	1.2	0.8	1.7	59	1.5
11. 09–12— 19	0.9	0.9	0.9	0.7	0.8	0.7	0.8	0.8[3]	0.3	0.2	0.5	63	1.0
12. 09–19— 21	17.2	17.0	17.1	16.8	17.8	18.0	18.2	17.7	14.3	4.4	3.4	19	16.5
13. 09–21— 25	26.8	22.3	24.5	26.7	27.0	22.9	24.0	25.2	17.9	5.3	7.3	29	20.5
14. 09–25—10–02	19.0	17.5	18.3	17.8	19.1	17.8	17.6	18.4[1]	13.1	3.6	5.3	29	16.0

[1] When the troughs were emptied on July 19 there was water in 10 troughs.
[2] The data for periods 6 and 7 are uncertain because the gauges were emptied during rain.
[3] R has been calculated using results from accumulators as well, because an error in trough No. 26 was suspected.

It can be inferred from Table 2 that the standard deviation of the 25 readings of the troughs under the canopy averages 58 % of the mean for throughfall amounts below 6 mm and 29 % for larger amounts. This means that the standard deviation of a mean value is $58/\sqrt{25} \equiv 12$ % and $29/\sqrt{25} \equiv 6$ % respectively.

In one period (No. 5 in Table 2) the rain amounts in the western clearing were about 25 % larger then in the eastern. In most cases however, this difference was less than 10 %. Since the two clearings are situated on either side of the area for measuring throughfall, this effect is probably not important for most interception values.

Because of the sloping of the troughs the catchment area is not the same for different wind directions. The troughs slope 10 degrees towards the south. The decrease of the area and thus of the collected rain amount is 6 % when the zenith angle of rainfall turns from 10 degrees south to 10 degrees north. However, such a dependence on the wind direction cannot be seen from the measurements.

ESTIMATES OF STORAGE CAPACITY AND FREE THROUGHFALL COEFFICIENT

Values of $S \equiv kR_0$ and p typical for the canopy in the Velen area will now be estimated.

Analysis of trough data

The model described above will give values for p or S for *one* storm according to

$$p = T/R \text{ if } R \leqq R_0 \qquad (1b)$$

$$S = R\text{-}T \text{ if } R \geqq R_0 \qquad (2b)$$

Before we can try these relations on the data we should have some idea of the value of R_0. In Table 3, both p and S are calculated for all periods. In each of the six columns to the right a fixed limit R_0 is assumed according to which a given rain amount on the OTA record will be: "small" if it is less than R_0, and "large" if it is greater. In the former case p is calculated using (1b) and in the latter case S is given by (2b). If there is more than one "large" rain storm, then $S \equiv R\text{-}T$ has to be divided by the number of "large" storms (N in Table 3) to obtain S for *one* storm. In the bottom of the Table, R_0 is calculated for each column as S/(1-p). This value should be the same as that assumed. We see that the agreement is best for $R_0 \equiv 4$ mm indicating also that $S \simeq 2$ mm and $p \simeq 0.5$.

Table 3.

Estimating free throughfall coefficient p and storage capacity S assuming various values of R_0. The agreement between calculated R_0 (see bottom of Table) and assumed R_0 is best for $R_0 = 4$ mm

Period no. (Table 2)	R	T	$p = \frac{T}{R}$	S=R–T	N	$R_0 = 1/2$ mm		$R_0 = 1$ mm		$R_0 = 2$ mm		$R_0 = 4$ mm		$R_0 = 6$ mm		$R_0 = 8$ mm	
						p	S	p	S	p	S	p	S	p	S	p	S
1.	3.3	1.7	0.53	1.5	2		0.8		0.8	0.53		0.53		0.53		0.53	
2.	6.5	4.5	0.69	2.0	1		2.0		2.0		2.0		2.0		2.0	0.69	
3.	23.2	14.2	0.61	9.0	6		1.5							0.61		0.61	
4.	7.0	4.2	0.60	2.8	3		0.9							0.60		0.60	
5.	36.1	27.1	0.75	9.0	11		0.8										
6.	62.2	55.0	0.88	7.2	9		0.8										
7.	56.5	39.9	0.71	16.6	9		1.8										
8.	11.6	9.5	0.82	2.1	1		2.1		2.1		2.1		2.1		2.1		2.1
9.	16.4	11.0	0.68	5.3	6		0.9										
10.	2.9	1.2	0.41	1.7	2		0.9	0.41		0.41		0.41		0.41		0.41	
11.	0.8	0.3	0.38	0.5	1		0.5	0.38		0.38		0.38		0.38		0.38	
12.	17.7	14.3	0.81	3.4	2		1.7		1.7								
13.	25.2	17.9	0.71	7.3	10		0.7										
14.	18.4	13.1	0.71	5.3	3		1.8		1.8		1.8						
					$R_0 = \frac{S}{1-p}$:			2.8		3.5		3.6		4.1		4.5	

Table 4.
Treatment of data from September 25–October 2
(Period no. 14 in Table 2)

Date	OTA mm	
Sept 28	9.5 ("large")	$R_1 - T_1 = S$
Sept 29	4.5 ("large")	$R_2 - T_2 = S$
Sept 30	2.0 ("small")	$R_3 - T_3 = kR_3$

In the following evaluation we will treat rain amounts smaller than 4 mm according to equation (1a) and larger amounts with equation (2a).

In Table 4 the different rain storms within the 14th period of Table 2 are given with their appropriate equations.

The model is applied in turn on each rain amount. We get three equations which, when added, become:

$$R\text{-}T = kR_3 + 2S \tag{3}$$

k and S are the unknown quantities. R is the total rainfall recorded by troughs in clearings. T is the throughfall below the canopy. R_3 stands for the sum of all "small" rain amounts and is calculated as the difference between R and the sum of "large" amounts recorded. Substituting in equation 3 we get from Tables 2 and 4:

$$18.4\text{-}13.1 = k(18.4\text{-}9.5\text{-}4.5) + 2S \tag{4}$$

Since the difference in the brackets is a "trough value" minus two "OTA values" there is probably a systematic error attached to it. We want to correct the OTA values so that they correspond to trough values which are used elsewhere in the equation. The OTA values to be corrected are those recorded as "large" amounts. In Table 2 there are two periods with only *one* large amount in them (2 and 8). They give for "trough minus OTA" 1.0 and 1.1 mm respectively. A study of other periods supports the correction + 1.0 mm to the "large" OTA values.

The equation (4) is changed into

$$18.4\text{-}13.1 = k(18.4\text{-}9.5\text{-}1\text{-}4.5\text{-}1) + 2S \tag{5}$$

The two alternative methods for getting the relation between k and S lead to the following Table:

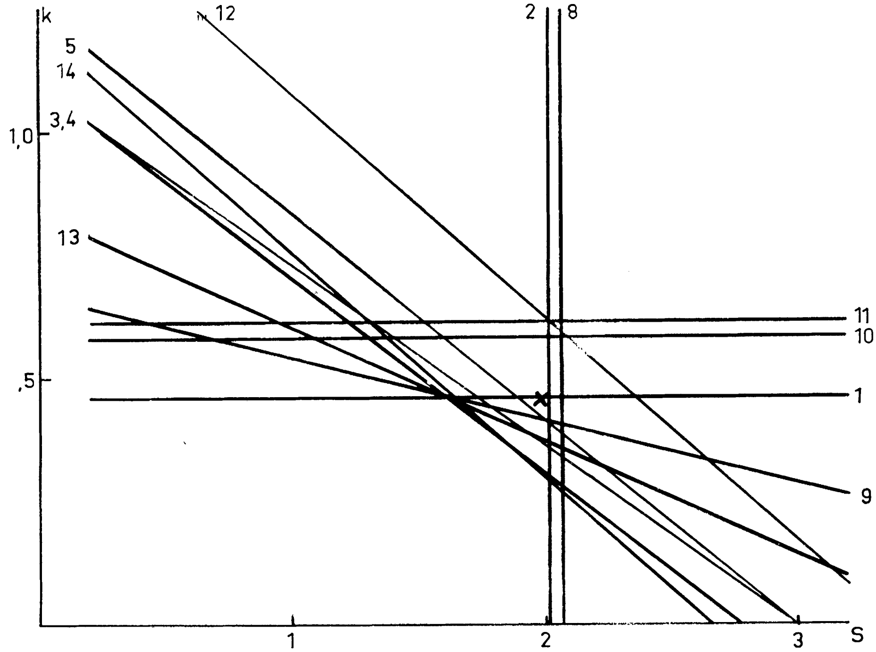
Table 5.
The equations for each period are obtained by adding the model equations for the single rain storms. In the bottom is given the least square estimate of average S and k

Period	Equations uncorrected for OTA	Equations corrected for OTA (if so required)
1	k = 0.47	k = 0.47
2	S = 2.02	S = 2.02
3	9.02 = 8.21k + 3S	9.02 = 5.21k + 3S
4	2.79 = 2.5k + S	2.79 = 1.5k + S
5	9.01 = 7.07k + 3S	9.01 = 4.07k + 3S
6	7.21 = 3.17k + 4S	7.21 = −0.83k + 4S
7	16.61 = 11.0k + 4S	16.61 = 7.0k + 4S
8	S = 2.06	S = 2.06
9	5.31 = 7.85k + S	5.31 = 6.85k + S
10	k = 0.59	k = 0.59
11	k = 0.62	k = 0.62
12	3.4 = 2.2k + S	3.4 = 1.2k + S
13	7.29 = 8.66k + 2S	7.29 = 6.66k + 2S
14	5.33 = 4.38k + 2S	5.33 = 2.38k + 2S
Average point (see the text)	S = 2.0 k = 0.46	S = 2.1 k = 0.56

The periods 1, 2, 8, 10 and 11 where there are only "large" or only "small" amounts give a definite value of S or k independent of the correction discussed.

In Fig. 4 the equations of the two cases of Table 5 (uncorrected for OTA and corrected for OTA respectively) are represented graphically in a coordinate system with axes S and k. Periods 6 and 7 are excluded, since the troughs were emptied during a rain period. All lines are seen to intersect each other in a rather small region. To get a representative average point, the sum of the squares of the distances from a point (S,k) to the lines was calculated. The point S,k for which this sum is smallest is given at the bottom of Table 5 for the cases and is marked in Fig. 4.

The average point for the first set of equations (upper diagram of Fig. 4) is situated below the intersections of the "fixed lines" parallel to the axes (1, 2,



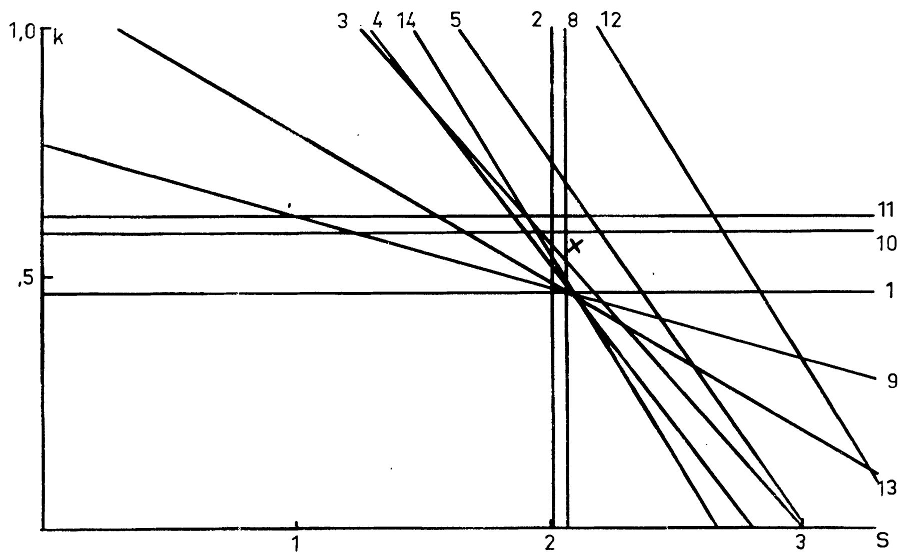


Fig. 4.
Graphical representations of the two sets of linear relations in Table 5. Upper: uncorrected for OTA. Lower: corrected for OTA. The cross sign in each diagram marks the point for which the sum of the squares of the distances to the 12 lines is a minimum.

8, 10 and 11). In the lower diagram the agreement between fixed lines and sloping lines is better, which favours the correction made from OTA. However, the values of canopy storage capacity are rather equal in the two cases: $S = 2.0$ and 2.1. The values of k differ somewhat more, corresponding to averages of the free troughfall coefficient p of 0.54 and 0.44, respectively.

The conclusion is that:

a) the overall canopy storage capacity is $S \simeq 2$ mm

b) the free troughfall coefficient is $p \simeq 0.5$

c) the capacity averaged over the horizontal area "shadowed" by canopy material, or the limit between a "small" and a "large" rain amount in the model is $R_0 \simeq 4$ mm.

Analysis of photographs for checking the free throughfall coefficient

In order to obtain a rough but independent check of the value of the free throughfall coefficient p, the sky and canopy were photographed upwards from

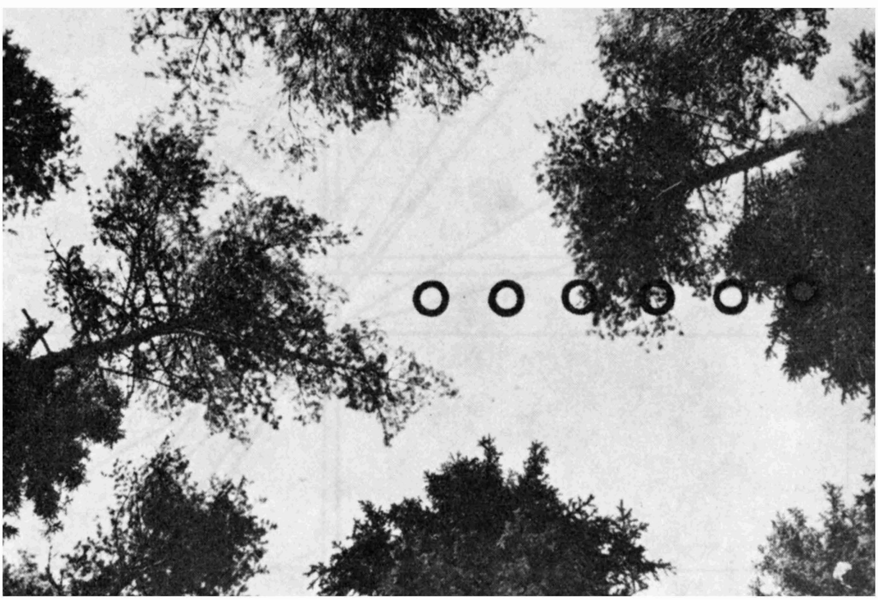


Fig. 5.

Vertical photograph of the canopy. Out from the middle are points indicated by circles spaced 1 cm apart. The numbers counted from the middle are 0, 0, 0, 1, 0, 1. (0 if free sky, 1 if canopy material).

the two ends of each trough. Such a photograph is given in Fig. 5. A spirit level on the camera house was used during each exposure to fix the zenith in the middle of each photograph.

In evaluating a photograph a centimetre scale was placed on it with the zero point in the middle. For each point given by the centimetre marks, 0 or 1 was written according to whether free sky or canopy material was seen. A series of

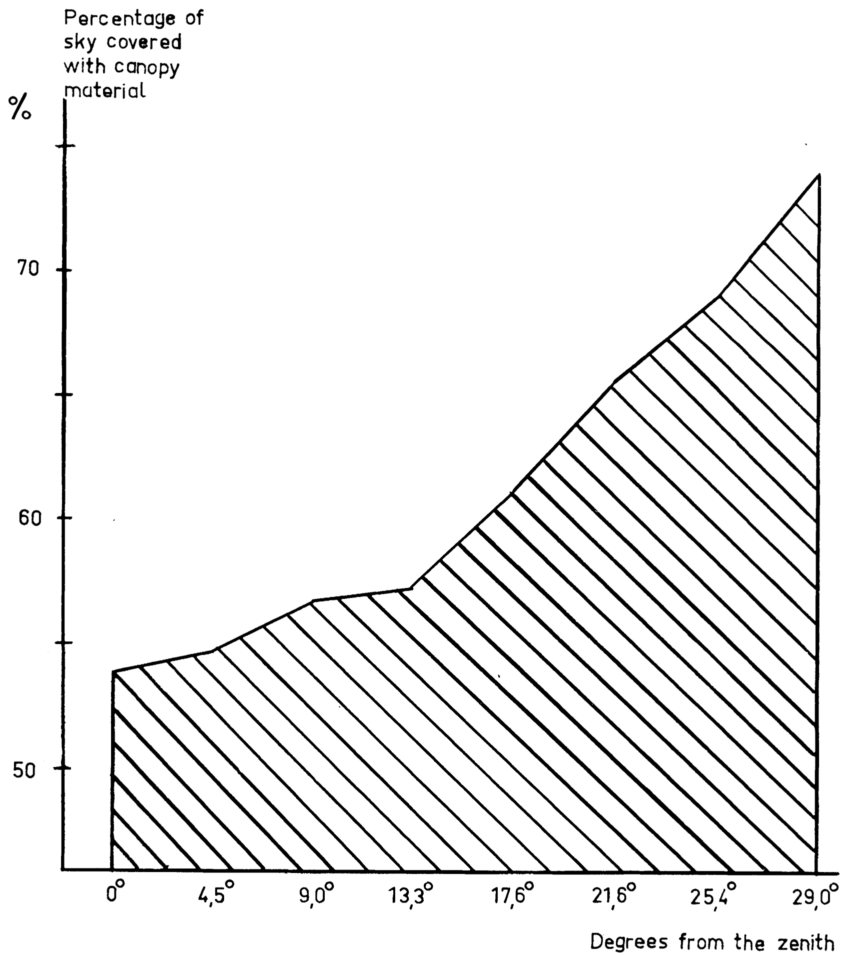


Fig. 6.
Proportion of sky covered with canopy material as a function of the angle of inclination of the line of sight. Each value is per cent of up to 500 readings on 50 photographs taken below the canopy.

readings was made for ten directions radiating from the center of the photograph. The points for one such direction are marked by circles in Fig. 5.

The result is given in Fig. 6. Some 55 % of the vertical lines of sight are against canopy material. This corresponds to $k \equiv 0.55$ or a free troughfall coefficient $p = 0.45$. This agrees with the value found from the troughs $p \simeq 0.5$. However, typical values of the rate of fall of the raindrops and wind speed above the canopy (about 5 m/s and 3 m/s respectively) give zenith angles of the order of 30° for the falling path. According to Fig. 6 this corresponds to 75 % coverage by canopy material or $p \equiv 0.5$. Two possible explanations for getting a lower free throughfall coefficient from the photographic data than from the trough data are:

1. The mean wind speed component in the general direction decreases as the raindrop reaches lower levels in the canopy and trunk space and the drop will be forced to fall more and more vertically. A calculation shows that this effect is important. Moreover, a large part of the percentage seen as canopy material on the photographs (Fig. 6) is probably low branches and trees (see Table 1) where the path is closer to the vertical.

Table 6.
Comparison of results

	Rutter et al.	The present paper
Number of trees per ha	600	$\simeq$ 750 higher than 10 m $\simeq$ 1000 higher than 5 m $\simeq$ 1500 higher than 1.5 m
Tree species	Pinus nigra	Pinus silvestris Picea abies Betula verrucosa
Mean height	20 m	22 m
Free throughfall coefficient p	0.25	0.5 (photographs give smaller values)
$k = 1 - p$	0.75	0.5
Overall storage capacity S	1 mm	2 mm
Storage capacity per area taken up by canopy material R_0	1.3 mm	4 mm

2. Even when the canopy is dry, a raindrop striking a branch or twig may be split up into smaller drops and some of them can reach the ground. This would give larger throughfall than can be inferred from the photographs.

Comparison with literature

In Table 6 our results are compared with those of Rutter et al. (1971).

It can be seen that the values of both S and p are different in our study. The larger storage capacity in the Velen forest is probably due to the large numbers of both low and high trees.

To find a reason for the larger value of free throughfall coefficient p in the Velen forest is more difficult, as the tree density is larger. It is possible that the tree crowns are thinner. As seen above, we have been forced to test a correction on the OTA record. A better record of the small rain amounts (with an accuracy of 0.2 mm instead of 0.5 mm) would give a safer value of p.

RATE OF EVAPORATION FROM CANOPY OF INTERCEPTED WATER

We will try to estimate how long a rain-free interval must be in order that a considerable part of the water intercepted on the canopy will evaporate. The length of every rain-free interval was evaluated from the OTA record. For each operative period of the troughs we counted the number of rain-free intervals exceeding a predetermined number of hours. In Table 7 we see, for example, that in period 5 there were 11 rain-free intervals longer than 2 hours and 10 intervals longer than 3 hours.

We see that the numbers of rain-free intervals longer than 4–5 hours are best correlated to the intercepted water amounts. Fig. 7 shows the relationship for 5 hours.

It seems that

a) in too short intervals the intercepted water cannot evaporate completely and

b) in counting long intervals only, we neglect shorter intervals in which water is evaporated.

In Fig. 7, the relation for 5 hours seems to be a straight line with a slope corresponding to 1–1.5 mm of evaporated rain per interval. This is smaller than the value of 2 mm found for storage capacity. However, we have also counted

Table 7.
Counts of rain-free intervals exceeding predetermined numbers of hours. To the right are given the amounts of intercepted water R-T. At the bottom is given the rank correlation coefficient between counts and the amounts R-T

Operative period of troughs	Predetermined number of hours															R-T mm
No.	1	2	3	4	5	6	8	10	12	14	16	18	20	22	24	
1	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1.5
2	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2.0
3	7	7	7	7	7	7	5	5	5	4	4	4	4	4	4	9.0
4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2.8
5	12	11	10	9	9	9	8	7	7	6	6	6	6	6	6	9.0
6	10	8	7	6	5	5	5	5	4	4	2	1	1	1	1	7.2
7	18	15	13	11	11	10	9	9	9	8	6	6	6	6	5	16.6
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2.1
9	6	6	6	5	4	4	3	3	3	3	3	3	3	3	3	5.3
10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.7
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5
12	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3.4
13	9	7	5	5	5	4	2	2	1	1	1	1	1	1	1	7.3
14	3	3	3	3	3	3	3	3	2	2	2	2	2	2	1	5.3
Rank correlation		0.86		0.91		0.86		0.80		0.66		0.54		0.64		
coefficient	0.81		0.89		0.91		0.80		0.67		0.62		0.64		0.59	

here the rain-free intervals after the smallest showers giving intercepted amounts smaller than 2 mm.

Since the OTA recorder is probably missing some small amounts, the real counts will be larger in the left part of Table 7 and smaller in the right part. It is difficult to say if this would change the results.

CONCLUSIONS

Neglecting stemflow the study of interception requires knowing the difference between total rainfall and throughfall. To eliminate errors due to differences between types of gauges, only values from troughs have been used for both rainfall and throughfall.

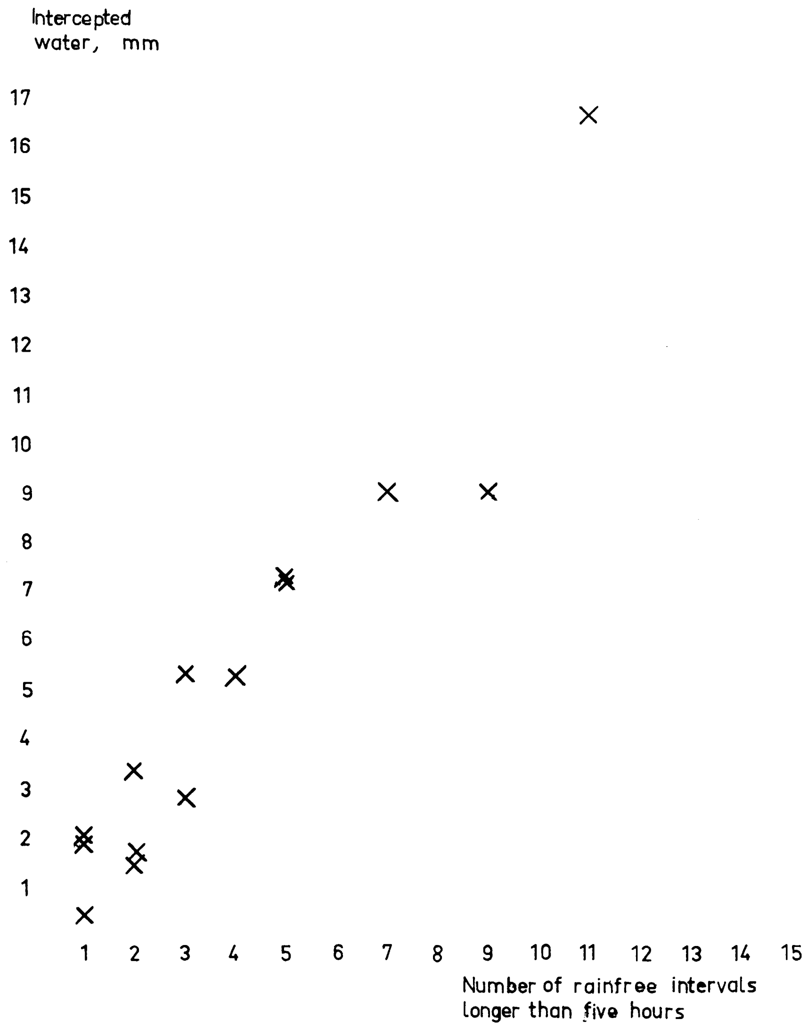


Fig. 7.

Each point represents intercepted water and number of rain-free intervals longer than 5 hours during *one* of the 14 operative periods of the troughs.

The model tested assumes that throughfall T (mm) for *one* rain event is

$$T = pR \text{ if } R \leqq R_0 \text{ and}$$

$$T = R\text{-}S \text{ if } R \geqq R_0$$

where R is the total rainfall, R_0 is a critical amount and $S = (1\text{-}p)\, R_0$.

S and p are the canopy storage capacity (mm) and the free throughfall coefficient respectively.

The limited set of data (14 operative periods from May 17 to Oct 2) gives the estimates that $S \equiv 2$ mm, $R_0 \equiv 4$ mm and $p \equiv 0.5$. An independent value for p was obtained from an evaluation from photographs of the percentage of free sky visible from the troughs. This study indicates that p should be smaller than 0.5.

A crude estimate gives a characteristic value of 5 hours for the time of evaporation of intercepted rain water on the forest canopy.

The amount of intercepted water for the period May 17 to Oct. 2 was 74 mm compared to a total rainfall of 288 mm. This means that 26 % of the total rainfall was intercepted.

The results of this study are based on 14 operative periods of the troughs. Many of them are more than 2 weeks long and contain several rainstorms.

To improve the quality of the data to be taken in 1974 the operative periods of the troughs should be made shorter.

Some additional troughs should be set up in the clearings around the forest area used for measuring throughfall. The OTA tipping-bucket gauge (accuracy 0.5 mm) should be supplemented with another gauge with an accuracy of 0.1 or 0.2 mm.

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