FOG PRECIPITATION IN FORESTS AND ITS MEASUREMENT II

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FROM

THARANDTER FORSTLICHES JAHRBUCH
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In the 1932 volume of this review the writer published under the same title the first set of observations made by the fog-measuring station near the Office of the Kriegwald forest district in the Erzgebirge from 1928 up to and including 1929. After a lapse of three years it seems desirable to publish the results for 1932 to 1934 inclusive and to compare them with the former data.

For the details of the establishment of the fog-measuring station at Kriegwald I must refer the reader to the aforementioned publication; I repeat only the points most necessary to a general understanding of the subject.

The station is situated in close proximity to the Kriegwald forest office at an elevation of 745 m. and consists of three units: a short distance from the northern edge of a 100 year old spruce stand in the middle of an older spruce plantation a fog meter (Nml) with two small rain-gages (Nm 5 and 6) has been set up; in the 100 year old spruce stand itself a second fog meter (Nm 2), around which are grouped four large rain gages (Nm 7, 8, 9, 10) with a catchment area of 1/2 sq. m. each; finally, southeast of the aforementioned, at a distance of about 250 m., a third fog meter (Nm 3 to 4) has been set up in a field adjacent to the office building.

The principal idea of this arrangement was to observe the horizontal fog precipitation within and without the forest, to measure its amount, and to establish comparisons.

The fog meter consists of an ordinary rain gage with a catchment area of 1/20 of a sq. m. above which 56 concentrically arranged aluminum rods about 1 m. long have been so fastened that they do not touch each other and their free ends protrude into the measuring apparatus. A steep roof protects the arrangement from rain and snow. The latter have seriously interfered with results during the first period (1928-1929 up to and including 1931) by being blown in laterally. For this reason the roofs were extended so as to eliminate this.

500 cm²
500 cm² = π r²
r = √(500/π)
= 12.6 cm
D = 25.2 cm

⇒ 2500 cm²
= 0.25 m²

∴ c/s area of 56 rods is > c/s area of coll.

Since July 1932 no appreciable amount of rain has been blown in laterally; in the case of blizzards, it is true, we know of no remedy to counteract this inconvenience.

The readings are carried out as in rain gages, in mm. of precipitation per square meter of horizontal catchment area. The amount of horizontal precipitation evidently depends upon the vertical catchment area superimposed upon the horizontal. As a norm we use a one square meter vertical catchment area superimposed upon a horizontal one of the same size. The vertical catchment area of our fog meters amounts, however, to only about 1/3 square meter, so that the results must be tripled to reduce them to the norm. The amount of fog precipitation in forests depends entirely upon the nature of the forest, especially the size and density of the crowns of the individual trees, because the longer the crown, the more numerous the needles or leaves and the greater the vertical catchment area superimposed upon the horizontal. The beginning and end of each observation period were determined by the weather; snow being blown in laterally and freezing and thawing of the melted water caused such great inaccuracies in the measuring of small quantities of water that it would be useless and even misleading: as a rule, at the elevation referred to the Erzgebirge, this period of unfavorable weather conditions lasts from the middle of November to the middle of April. As a result the months with the heaviest fog are not measured, especially the period of hoar frost so characteristic of the Erzgebirge, which frost evidently puts a considerable amount of precipitation upon the forest floor. Table 1 shows rain and fog precipitation during the periods of 1932, 1933, and 1934. Fog meter 1 (in the spruce plantation) almost always yields smaller figures than fog meter 3, in an isolated position (in the field); the reason is probably the more isolated position of the latter. It is more striking that fog meter 2, located in an old spruce wood, almost always yields the highest figures, the only exception being April 1933.

This strange result was mentioned in the first publication; it has been confirmed and even strengthened, as is clearly shown by a comparison of the figures. A sound explanation of this has not yet been found.

Fog meter 3-4 really consists of two apparatus located under one roof, one of which has a normal number of rods (36) while the other has only 28. The purpose of this arrangement is to prove that, all other conditions being similar, fog precipitation depends upon the size of the vertical catchment area. The result from 1932 up to and including 1934 is fairly satisfactory as is shown by the following figures: 1932, 1.92 mm. and 0.98 mm.; 1933, 3.38 mm. and 1.94 mm.; 1934, 1.82 mm. and 1.0 mm. The figures obtained from 1929 up to and including 1931 showed, it is true, greater harmony: for 1929, 7.67 mm. and 4.45 mm.; for 1930, 4.30 mm. and 3.69 mm. and for 1931, 2.05 mm. and 1.96 mm. An important reason for this difference must doubtless be sought in the fact that fog precipitation in the period

from 1930 up to and including 1934 is generally so very small that inaccuracies may easily occur in the readings. Rain gages 5 and 6 in the spruce plantation beside fog meter Nm 1 yielded quite harmonious results; the greatest differences were shown in the months of the measuring period most rich in fog, namely, April, October, and November. The rain gage set up adjacent to the forest office building generally shows a much higher monthly mean which cannot be explained in detail; the same result was found in 1929 and 1930, though in these years the differences were smaller.

The average monthly precipitation which reached the forest floor fluctuated between 60.7% and 106.5% in 1932; the latter figure can be explained only on the basis of a high amount of horizontal precipitation. As a matter of fact, for November 1932 we find that of the 14 observation days there was fog precipitation on 7 days, whereas out of the 30 and 31 observation days of September and October of the same year only two days in each showed fog precipitation, thus explaining the small percentage, about 61% for each, which reached the forest floor. It is to be noted, it is true, that the fog precipitation in the forest may reach high figures also without the aid of horizontal precipitation, namely when heavy precipitation (20 mm. within 24 hours) occurs fairly frequently, whereas frequent but small precipitations (below 5 mm.) result in a lower percentage penetrating through the canopy.

In 1933 the precipitation that reached the forest floor fluctuated between 40.4% and 88.5%. The former figure refers to only 9 observation days in November with only 2 foggy days. Furthermore, this statement is not entirely reliable since at that time there were frosts and blizzards. The percentage was likewise very small in October of that year, amounting to 51%. Rains in this month were frequent, but were never greater than 4.3 mm. in 24 hours. They were, therefore, in a large part intercepted by the crowns. Without the 8 foggy days the precipitation reaching the forest floor would doubtless have been still smaller. In 1934 the extremes are 43.3% and 95.5%. The first figure holds true for the very dry May (only 22 mm. in an isolated rain gage) which had very light rains on 11 days (with one exception they were all below 3.5 mm.) and only 1 foggy day. April 1934, with an amount of precipitation reaching the forest floor equal to 95.5% of the precipitation in the open country, had 5 days with fog precipitation out of 10 precipitation days.

More details concerning the importance of fog or of horizontal precipitation on the amount reaching the forest floor are given in Table 2. In this table precipitation has been divided according to foggy and fog-free days; for each of these two groups the absolute maximum reaching the forest floor has been given and also the percentage, i.e. the largest precipitation of the 4 large rain gages.

For 1933 the maximum precipitation reaching the forest floor is more than 100% (up to 156%) in most cases during the individual months; only in two cases does it fall below with 97% and 96%. Conversely, maximum precipitation in forests on fog-free days always falls below 100% (it may even drop to 56%), approaching 100% in only one month. On the average, for the entire observation period of 1932 we found a maximum precipitation reaching the forest floor of 110% on foggy days contrasted with only 86% on fog-free days.

The conditions were much the same in 1933. A clear result was also shown in 1934 for the average of the entire observation period (106% as compared with 75%) with but one exception caused by inexact measurements due to snow and frost and explained in the column under "remarks".

The investigation result pointed out in my first publication is fully confirmed by the precipitation measurements from 1932 up to and including 1934. There can, therefore, be no doubt that in favorable places in the forest more water can reach the forest floor than in the open country because of the horizontal and vertical precipitation. The small and frequently hardly measurable fog precipitation of the summer, thus becomes of considerable importance for the water regime of the forest. The cause must be sought in the fact that the fog causes a pronounced wetting of needles and leaves so that even a small precipitation reaches the forest floor. More than 90% of a heavy precipitation, as pointed out above, may reach the forest floor even without the cooperation of horizontal precipitation.

Those days on which there was only fog and no rain are of importance in determining the quantity of the horizontal precipitation in forests (without vertical precipitation). The water in the rain gages set up within the stand can, therefore, have originated only in horizontal precipitation. Table 5 gives a list of the days since 1930 on which such was the case. They amount to only 10, of which 2 had to be combined under one measurement. Apart from the water collected in the fog meters we have given that collected in the 4 rain gages, their mean, and the mean of that of the 2 isolated fog meters 1 and 3. The quotient of the rain gage mean divided by the fog meter mean, likewise given, indicates how much the quantity of water of the former exceeds that of the latter.

As in all precipitations, so also in pure fog precipitation Rm 8 showed the smallest amount of water. Rm 9, otherwise showing a maximum precipitation, lags far behind Rm 10. On such days the daily averages of fog precipitation of Nm 1 and 3 are very uniform with 0.12 or 0.13 mm. Nm 2, set up in the spruce stand, gives again the largest figure, namely, a daily average of 0.20 mm. The quotient of the rain gage precipitation divided by the fog meter precipitation amounts on the average to 0.4. This means that on the average there is a much greater vertical catchment area in proportion to the

horizontal area in the forest than in our fog meter. For the stations this quotient fluctuates very much, namely, between 2.3 and 23.5 as is shown by Table 3. To determine the actual vertical catchment area above 1 square meter of forest floor in our spruce stand, we must remember that by far the largest part of fog precipitation remains in the tree crowns and, as I assumed in my early work, probably only 10% reaches the forest floor in case of small horizontal precipitation. Under this supposition a vertical catchment area would amount to 1/3 x 8.4 x 10 = 28 square meters (as compared with 20 square meters in my early work). The agreement is sufficient if we consider that the 10% represent only a rough estimate for average conditions which are bound to be very different according to the size and duration of horizontal precipitation.

To sum up, we may say that on the basis of fog measurement observations carried on for 6 years in the Erzgebirge at an elevation of 748 m.:

1. The fog meter has proven satisfactory; the extended roof has completely eliminated the effect of laterally blown rain, though even this construction is not effective against blizzards.

2. Fog precipitation reaching the forest floor during the vegetative period (from May to September inclusive) is numerically very small, amounting at most to 1 to 2 mm. for one square meter of vertical catchment area; heavier fog precipitation may occur in April, October, and November.

3. These small quantities gain importance because, according to the nature of the stand, the vertical catchment area may be increased 20 or even 28 times. On the other hand it must be considered that only a small percentage of the fog precipitation reaches the forest floor, on the average presumably only 10%.

4. Horizontal precipitation gains still greater importance by its connection with vertical precipitation. The former wets the needles or leaves, after which even light rains may reach the forest floor more easily than is possible without fog precipitation. In some parts of the stand the total precipitation may then exceed the precipitation in the open country by 30, 40, and even 50%.

5. In the winter fog precipitation may supply the forest floor with very large quantities of water which are of importance for the water regime of the forest. Up to now it has been possible to make only occasional observations with our fog meters because of the frosts and blizzards common in winter.

A measuring station set up in the spring of 1934 near the Carlsfeld Dam in the western part of the Erzgebirge at an elevation of 900 m., a station which at present is only temporary, has shown very high forest precipitation for the first part of December of 1934. We postpone publication of the data until further observations have been made.

Table 1

Fog and Rain Precipitation

	Location of instrument	Instrument No.	1932 Apr. (18-30)	May	June	July	Aug.	Sept.	Oct.	Nov. (1-14)	Total	Remarks
Fog precipitation in (mm.) per 1/3 sq. m. of vertical catchment area (in No. 4 per 1/6 sq. m.)	Plantation	1	0.05	0.12 (1.04)	0.35 (0.39)	0.05	0.08	-	0.02	0.31	0.68 (1.94)	Figures in parentheses =total fog precipitation+rain (or snow) blown in.
	Forest	2	0.17	0.77 (1.44)	0.13 (0.15)	0.37	0.17	0.06	0.13	1.80	3.60 (4.20)	
	Field	3	0.20	0.43 (0.74)	0.06 (0.12)	0.19	0.06	0.02	0.04	0.79	1.[illegible] (2.16)	
	Field	4	0.10	0.22 (0.57)	0.05 (0.10)	0.06	0.03	0.01	0.02	0.45	0.92 (1.14)	
Total precipitation in mm.	Mean	(1 + 3)/2	0.13	0.28 (0.89)	0.06 (0.26)	0.12	0.07	0.02	0.03	0.55	1.26 (2.07)	
	Plantation	5	0.5	157.6	117.1	149.3	51.1	39.3	83.7	35.7	634.3	
	Plantation	6	0.5	154.8	117.2	149.3	50.7	38.5	81.3	33.0	625.3	
	Mean	(5 + 6)/2	0.5	156.2	117.2	149.3	50.9	38.9	82.5	34.4	629.9	
	Precipitation in station rain gage		-	164.2	140.9	164.4	57.4	44.6	93.7	-	-	
	Forest	7	0.1	111.5	75.6	110.2	31.6	19.6	46.1	30.9	425.6	
	Forest	8	0.1	114.2	86.2	97.1	30.1	24.1	45.0	27.7	424.3	
	Forest	9	0.2	171.7	98.4	142.1	46.6	25.3	66.2	36.4	389.4	
	Forest	10	0.1	148.1	107.5	115.5	40.2	23.7	46.8	51.8	533.7	
	Mean	7-10/4	0.1	136.4	91.9	116.5	37.1	23.6	51.9	36.7	493.3	
Percentage of moisture reaching the forest floor		7/10 / 5/6	-	87.3	78.5	78.1	72.8	60.7	61.8	106.5	73.3	

Continuation of Table 1

	Location of instrument	Instrument No.	1933 Apr. (1-16 and 30)	May	June	July	Aug.	Sept.	Oct.	Nov. (1-9)	Total
Fog precipitation in (mm.) per 1/5 sq.m. of vertical catchment area (in No. 4 per 1/6 sq.m.)	Plantation	1	0.70	0.01	0.05	0.23	0.64	0.09	0.05	0.32	2.09
	Forest	2	1.13	0.03	0.13	0.52	1.29	0.47	0.57	0.23	4.47
	Field	3	0.28	0.01	0.08	0.28	0.93	0.37	0.33	0.44	3.32
	Field	4	0.50	-	0.05	0.17	0.52	0.20	0.17	0.23	1.94
Total precipitation in mm.	Mean	(1 + 3)/2	0.79	0.01	0.07	0.26	0.79	0.23	0.19	0.38	2.72
	Plantation	5	76.8	59.3	129.8	84.1	146.8	55.0	21.6	38.4	611.8
	Plantation	6	67.9	59.4	128.8	82.9	136.4	52.9	20.7	32.0	581.0
	Mean	(5 + 6)/2	72.4	59.4	129.3	83.3	141.6	54.0	21.2	35.2	596.6
	Precipitation in station rain gage		-	70.1	152.7	92.0	161.7	64.9	45.5	-	-
	Forest	7	42.0	28.7	72.5	44.2	105.3	35.8	8.7	15.1	348.3
	Forest	8	36.0	22.8	74.6	40.8	103.4	25.4	13.8	12.3	329.1
	Forest	9	64.7	40.4	79.4	67.9	143.0	51.6	11.5	14.3	472.8
	Forest	10	54.7	27.8	86.0	56.5	150.8	44.1	9.1	15.2	454.2
	Mean	(7 - 10)/4	49.4	29.9	78.1	54.9	125.1	38.7	10.8	14.2	401.1
Percentage of moisture reaching the forest floor		(7 / 10)/(5/6)	68.2	50.3	60.2	65.8	88.5	71.7	51.0	40.4	67.2

Continuation of Table 1

	Location of instrument	Instrument No.	1924 Apr.	May	June	July	Aug.	Sept.	Oct.	Nov. (1 and 2)	Total
Fog precipitation (mm.) per 1/5 sq.m. of vertical catchment area (in No. 4 per 1/6 sq.m.)	Plantation	1	0.22	0.11	0.02	-	0.02	0.05	0.09	-	0.67
	Forest	2	0.76	0.44	0.11	0.02	0.08	0.30	0.27	-	2.00
	Field	3	0.89	0.21	0.02	-	0.07	0.12	0.22	-	1.52
	Field	4	0.63	0.10	0.01	-	0.04	0.08	0.14	-	1.00
Total precipitation in mm.	Mean	$\frac{1+3}{2}$	0.63	0.16	0.02	0.02	0.05	0.09	0.16	-	1.13
	Plantation	5	54.1	23.7	72.6	53.4	111.4	46.7	101.2	2.3	455.4
	Plantation	6	50.8	20.3	69.0	51.4	105.2	44.2	93.7	2.1	455.7
	Mean	$\frac{5+6}{2}$	52.5	22.0	70.8	52.4	108.3	45.5	97.5	2.2	451.2
	Precipitation in station rain gage		63.2	24.1	72.2	52.9	123.4	37.1	114.3	-	-
	Forest	7	48.3	10.3	41.6	29.1	73.7	32.3	65.0	0.6	300.9
	Forest	8	48.1	4.0	37.2	25.5	59.2	31.3	54.6	0.6	[illegible]
	Forest	9	43.7	11.0	49.3	39.2	96.2	41.2	68.7	0.7	350.0
	Forest	10	60.5	12.7	67.8	38.8	77.0	47.2	70.0	0.5	364.6
	Mean	$\frac{7-10}{4}$	50.2	9.5	49.5	32.7	76.5	38.0	64.6	0.6	318.6
Percentage of moisture reaching the forest floor		$\frac{7/10}{5/6}$	95.5	43.2	65.7	62.4	70.5	83.5	66.3	27.2	70.8

Table 2

Precipitation reaching the forest floor on foggy and fog free days

Time	Total precipitation days	Average precipitation reaching the forest floor in percentage of precipitation in the open	Foggy days with precipitation: Total	Fog precipitation in isolated fog water in mm.	Precipitation in isolated rain gage in mm.	Maximum precipitation reaching the forest floor in mm.	Maximum precipitation reaching the forest floor in %	Fog free days with precipitation: Total	Precipitation in isolated rain gage in mm.	Maximum precipitation reaching the forest floor in mm.	Maximum precipitation reaching the forest floor in %
1962											
May	18	87	7	0.45	91	117	129	11	66	50	76
June	18	79	8	0.06	81	91	111	10	86	69	81
July	19	78	5	0.19	39	38	96 1/	14	110	109	99
Aug.	11	75	2	0.06	19	24	129	9	38	33	70
Sept.	13	61	2	0.02	12	10	87	11	27	18	64
Oct.	17	62	5	0.04	66	39	109	14	46	28	95
Nov.1-14	8	107	2	0.79	34	52	156	1	1	1	-
	104	78	34	1.59	312	371	119	70	321	258	80
1963											
May	20	30	1	0.01	2	1	-	19	97	40	70
June	19	60	4	0.06	29	24	83	16	99	79	80
July	16	66	4	0.28	48	58	124	12	41	25	61
Aug.	18	89	5	0.93	93	117	119	7	44	41	93
Sept.	9	72	4	0.37	91	82	105	5	33	30	91
Oct.	13	51	8	0.33	11	16	145	5	10	3	30
	95	67	26	2.00	284	253	114	63	284	218	77
1964											
Apr.	11	95	6	0.88	39	53	136	5	18	8	61
May	10	44 2/	1	0.21	4	4	100	9	18	10	56
June	7	66	2	0.08	98	34	103	5	38	25	66
July	13	62	0	-	-	-	-	13	82	48	88
Aug.	13	71	4	0.07	60	57	91	9	49	38	78
Sept.	9	84	3	0.12	33	33	144	6	23	15	65
Oct.	14	66	4	0.88	31	24	77 3/	10	66	53	80 3/
	77	71	20	1.82	189	205	108	57	259	194	75

1/ Not reliable, rain gauge overflowed.
2/ Only one precipitation amounted to more than 3 mm.
3/ This exception is due to inexact date as a result of snow and frost.

Table 5

Summary of pure fog precipitation, 1930-1933.

Day	Fog meter 1 (Plantation)	Fog meter 2 (Forest)	Fog meter 3 (Field)	Rain gage 7	Rain gage 8	Rain gage 9	Rain gage 10	Mean of the 4 rain gages	Mean of fog meters 1 & 3	Rain gage / Fog meter
10/16/1930	0.30	0.62	0.19	1.45	0.44	0.61	0.95	0.84	0.25	3.4
10/17/1930	0.06	0.18	0.04	0.32	0.12	0.14	0.45	0.36	0.05	5.2
7/ 6/1931	0.06	0.14	0.03	0.22	0.31	0.60	0.60	0.43	0.05	8.6
11/11/1932	0.11	0.57	0.24	3.50	2.50	3.60	6.30	4.00	0.17	23.5
11/12/1932	0.03	0.12	0.14	1.10	0.80	1.30	2.30	1.40	0.08	17.5
4/8-9/1933	0.17	0.51	0.29	0.44	0.36	0.95	1.13	0.72	0.23	3.2
4/14/1933	0.11	0.36	0.17	0.10	0.13	0.46	0.44	0.28	0.14	2.0
10/23/1933	-	0.06	0.04	0.51	0.30	0.21	0.25	0.29	0.04	7.2
10/24/1933	-	0.06	0.01	0.20	0.10	0.10	0.18	0.14	0.01	14.0
Total Average	0.84 0.12 mm.	2.62 0.29	1.15 0.13 mm.	7.84	4.96	7.97	12.60	3.36 0.92 mm.	1.08 0.11 mm.	92 8.4