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AMOUNT OF THROUGHFALL AND STEMFLOW IN A SHORTLEAF PINE PLANTATION AS RELATED TO RAINFALL IN THE OPEN

W. R. BOGGESS
University of Illinois, Dixon Springs Station, Robbs

The amount of rainfall reaching the ground in an open area and in an adjacent timber stand will differ considerably. A part of the rain falling on a forest drops directly through the canopy. The remainder is intercepted by the crowns of the trees. Some of the intercepted moisture evaporates directly into the atmosphere, but a much greater part (except in light showers) reaches the ground by dropping from the leaves and twigs or by flowing down the branches and stems. That part of the rainfall that evaporates directly into the atmosphere is known as *interception*. That reaching the ground directly or by dropping from the leaves and twigs is known as *throughfall*. The part that flows down the stem and into the soil is known as *stemflow*. The sum of the throughfall and stemflow makes up the *net rainfall*. Both stemflow and throughfall are influenced by many factors and differ widely between species of plants and localities. (Kittredge, 1948).

Net rainfall has been measured over a three-year period (May 1, 1951 to April 30, 1954) in a shortleaf pine (*Pinus echinata* Mill.) plantation located at the Dixon Springs Experiment Station, Pope County, Illinois. These measurements were made as a part of a study of trends in soil moisture under different types of vegetative cover.

Description of Stand

The shortleaf pine plantation was established during the spring of 1937. At the beginning of the study there were 800 pine trees per acre (3.6 inches in diameter and over) with a basal area of 110 square feet. During the three-year period, basal area increased to 135 square feet per acre and average diameter from 5.0 to 5.6 inches. All diameter measurements were made at a point 4.5 feet above the ground.

Methods

Measurements of throughfall and stemflow were made on three, one-fifth acre, unthinned, check plots of a previously established thinning experiment. Paired, standard rain gages were located on each plot. One gage was located under a heavy part of the canopy and another in the nearest opening. In most instances the openings were merely thin places in the canopy. Rainfall was also measured in an open area, adjacent to the plantation, by a standard and a recording gage. Rainfall was measured after each storm or as nearly so as practical. A storm was considered as a period of precipitation separated by at least six hours from any other period in which precipitation occurred. The locations of rain gages in the plantation were shifted periodically during the study.

TABLE 1.—Data on Rainfall Under the Canopy and Outside of a Shortleaf Pine Plantation, and at the Dixon Springs Experiment Station, 1951-1954.

	Rainfall in inches											
	Pine plantation						Official gage[1]					
	1951-52		1952-53		1953-54		Amount			Deviations		
	In open	Under trees	In open	Under trees	In open	Under trees	1951-52	1952-53	1953-54	1951-52	1952-53	1953-54
May	1.64	1.06	4.16	3.77	4.08	3.50	2.10	3.51	2.79	—1.89	—0.48	—1.20
June	11.15	8.87	2.29	1.87	2.76	1.92	10.75	3.53	3.03	+6.67	—0.55	—1.05
July	1.40	1.05	1.96	1.67	1.51	1.10	3.76	1.70	1.47	+0.56	—1.50	—1.73
Aug.	3.94	3.62	1.18	1.08	0.73	0.54	3.98	1.20	0.97	+0.30	—2.48	—2.71
Sept.	5.24	4.64	3.61	3.21	1.08	0.94	5.00	2.74	1.11	+1.43	—0.83	—2.46
Oct.	2.41	1.84	1.16	1.11	1.68	1.45	1.91	1.10	1.79	—1.48	—2.29	—1.60
Nov.	7.85	6.23	2.09	1.60	1.16	0.94	8.04	2.05	1.30	+4.47	—1.52	—2.27
Dec.	8.92	7.54	4.16	3.27	2.98	2.10	7.38	4.10	2.65	+3.67	+0.39	—1.06
Jan.	4.11	3.00	3.76	3.14	6.64	5.92	4.06	3.71	6.05	—0.46	—0.81	+0.83
Feb.	4.51	4.32	1.57	1.19	2.53	2.05	4.84	1.41	2.50	+1.75	—1.68	—0.59
Mar.	7.33	6.39	6.10	5.04	1.95	1.55	7.69	6.05	2.10	+3.11	+1.47	—2.48
Apr.	3.26	2.84	3.28	2.46	4.75	3.67	2.95	4.36	3.92	—1.51	—0.10	—0.54

[1] Maintained by the Dixon Springs Experiment Station in cooperation with the U. S. Weather Bureau. Listed in Weather Bureau Summaries as "Glendale Experimental Farm".

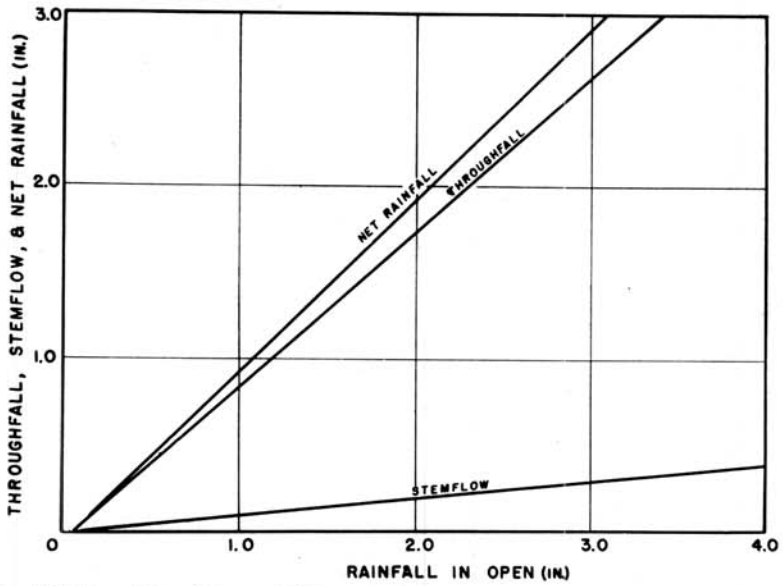

FIG. 1.—Relationship of throughfall, stem flow, net rainfall, and rainfall in the open.

Stemflow was measured during the final year of the study on ten trees located near the rain gages. Water flowing down the stems was caught in spiral gutters made from aluminum flashing and fastened to the trees with aluminum roofing nails. The top edge of the gutters was sealed with asphalt roofing cement. Water was led from the trees to five-gallon collection cans by a piece of plastic tubing. The amount of stemflow was determined by weighing the cans after each storm and converting the weights into inches of water per acre.

RESULTS AND DISCUSSION

The rainfall pattern differed considerably during the three-year period. The total precipitation for 1951-52 exceeded the 15-year average at the Dixon Springs Station by 15.9 inches. There was a deficit of 10.5 inches in 1952-53 and of 14.0 inches in 1953-54. Monthly precipitation under the canopy and outside the stand, as well as the official rainfall (collected for the U. S. Weather Bureau) at the Dixon Springs Station is shown in Table 1. Differences between the monthly totals at the official gage and that outside the pine plantation are due to the facts that: (1) the two stations are five miles apart; and (2) the weather bureau data are divided by days ending at midnight, while those for the pine plantation are recorded by storms. Occasionally, storms overlapped the last day of a month and the first day of the next month. In these instances the total rainfall for the storm at the pine plantation was recorded for the day on which the storm began and would therefore indicate a greater monthly total than that recorded at the official gage.

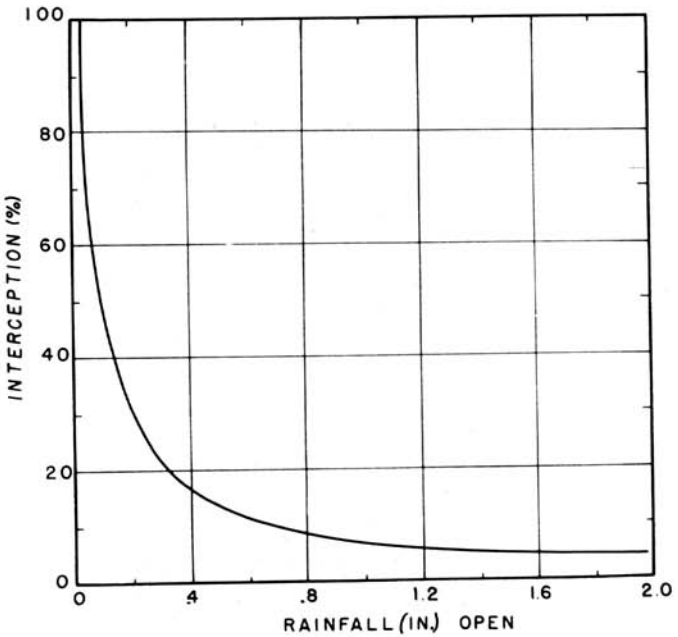

FIG. 2.—Relationship between interception and rainfall in the open.

June, 1951, was the wettest month during the three-year period (11.15 in.). The least rainfall was in August, 1953 (0.73 inches). The heaviest rainfall in a single storm (3.92 inches) fell on March 10, 1952.

Linear relationships were established between throughfall, stemflow, net rainfall, and rainfall in the open (Fig. 1). The equations are shown below:

Throughfall=0.8957 (rainfall in open)—0.0562

Stemflow=0.0982 (rainfall in open)—0.0045

Net rainfall=0.9939 (rainfall in open)—0.0607

The equation for throughfall is based on 157 storms which averaged 0.82 inches of rainfall. Stemflow is based on 35 storms in 1953-54 which averaged 0.84 inches. Although the percentage of throughfall is about 2.5% less in 1953-54 than in either 1951-52 or 1952-53, the regression equations for these years were not significantly different. Seasonal differences in the amounts of throughfall and stemflow were negligible.

Measurable amounts of stemflow did not begin until storms exceeded 0.20 inches in size. During the wet year of 1951-52, stemflow added a calculated 5.72 inches of moisture to the soil or 9.3% of the rain falling in the open. The amount of stemflow was less during the two dry years (1952-54), amounting to 7.9% of the total rainfall (Table 2).

The calculated interception by the canopy of the pine plantation (Table 2) amounted to 7.5% of the total rainfall in the open in 1951-52,

TABLE 2.—Number and Size of Storms, Inches of Total Rainfall, Throughfall, Stemflow, Net Rainfall, Interception, and Percent of Interception for a Shortleaf Pine Plantation, 1951-54.

Year	Storms		Inches of water					Percent interception
	No.	Size (in.)	Total rainfall	Throughfall	Stemflow	Net rainfall	Interception	
1951-52.....	67	0.92	61.76	51.40	5.72	57.12	4.64	7.51
1952-53.....	49	0.72	35.32	29.41	2.58	31.99	3.33	9.46
1953-54.....	41	0.78	31.85	25.68	2.73	28.41	3.44	10.91
Total.....	157	0.82	128.93	106.49	11.03	117.52	11.41	8.85

9.5% in 1952-53, and to 10.9% in 1953-54. The relation between interception and the amount of rainfall in the open is shown in Figure 2.

It is of interest to compare these results with data obtained by Hoover (1953) for a young loblolly pine (*Pinus taeda* L.) plantation near Union, South Carolina. He established the following relationships between throughfall, stemflow, net rainfall, and rainfall in the open:

Throughfall = 0.732 (rainfall in open)—0.016

Stemflow = 0.222 (rainfall in open)—0.018

Net rainfall = 0.954 (rainfall in open)—0.034

A comparison of the Union, South Carolina, and Dixon Springs data for storms of different size is shown in Table 3.

Throughfall was greater at Dixon Springs than at Union, while the opposite was true for stemflow. Net rainfall did not differ appreciably between the two locations. The difference in throughfall was undoubtedly influenced by the fact that the average rainfall per storm was 0.82 inches at Dixon Springs and 0.45 inches at Union. The percentage of throughfall increases sharply with the amount of rainfall and begins to level off when storms exceed one-half to three-quarters of an inch in

TABLE 3.—Amount of Throughfall, Stemflow, and Net Rainfall Calculated for Storms of Different Sizes in Plantations of Loblolly Pine at Union, South Carolina. and Shortleaf Pine at the Dixon Springs Experiment Station.

Storm Size	Throughfall		Stemflow: inches, water		Net rainfall	
	Union	Dixon Springs	Union	Dixon Springs	Union	Dixon Springs
0.50.....	0.350	0.392	0.093	0.045	0.443	0.437
1.00.....	0.716	0.839	0.204	0.093	0.920	0.932
1.50.....	1.082	1.287	0.315	0.143	1.397	1.430
2.00.....	1.448	1.735	0.426	0.192	1.874	1.927

size. The relationship is fairly constant above one inch. More than one-half of the storms at Dixon Springs were greater than one-half inch in size (Table 4). This is fairly typical of rainfall in this area. Page (1949) pointed out that the climate of Illinois is dominated by cyclonic storms with their accompanying interchanges of air masses. During the cooler parts of the year the long, low-pressure troughs, with cooler air to the north and warmer air to the south, frequently become stationary and result in two or three days of cloudy or rainy weather. Rains of two days' duration are not uncommon under these circumstances.

TABLE 4.—Classification of Storms at the Dixon Springs Experiment Station, 1951-54.

Storm size (inches)	Number of storms	Percent total storms
0-0.25	20	12.74
0.26-0.50	43	27.39
0.51-0.75	28	17.83
0.76-1.00	20	12.74
1.01-1.25	16	10.19
1.26-1.50	11	7.01
1.51-1.75	4	2.55
1.76-2.00	6	3.82
2.01-2.25	2	1.27
2.26-2.50	3	1.91
2.51-2.75	1	0.64
2.76-3.00	1	0.64
3.01-above	2	1.27

The amount of stemflow per storm was about twice as much for loblolly pine at Union as for shortleaf pine at Dixon Springs. These differences are probably related to characteristics of the two species since the average rainfall per storm was about the same for the two locations (0.80 inches at Union and 0.84 inches at Dixon Springs). While the volume of stemflow is considerably less for shortleaf pine than for loblolly pine, its importance in the redistribution of rainfall, as discussed by Hoover, should not be underestimated. In the slowly to moderately permeable soils, which occur on the uplands of southern Illinois, conditions are probably more favorable for moisture penetration at the bases of trees than at other locations within the stand. Thus a small volume of stemflow moisture might have as much, or more, beneficial effect on tree growth than a large amount occurring as throughfall. This would be particularly true in high intensity storms where runoff would become an important factor.

Interception may seem insignificant when considered on the basis of an individual storm. Its importance is realized when evaluated as an increment of the total precipitation for a period of a year or more. On an annual basis the amount of moisture intercepted by the forest canopy and evaporated back into the atmosphere is equivalent to almost a month's rainfall. Thus the amount of moisture available for plant growth, groundwater reserves, or streamflow is reduced by approximately one-twelfth the annual rainfall.

Interception losses are not limited to timber stands although more attention has been given to the forest than to other vegetative cover types. Man's attention was probably drawn to the relation of the forest and rainfall at an early date—he has long sought shelter from storms in the forest. Then, too, both throughfall and stemflow are more easily meas-

ured in the forest than under herbaceous covers. However, all types of cover intercept precipitation, some to a greater extent than others. Knowledge of all cover types is necessary to evaluate properly the effects of vegetation on watershed management.

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