JOURNAL OF HYDROLOGY
NEW ZEALAND

Published twice annually by the New Zealand Hydrological Society

Volume 18 1979 Number 2

RAINFALL INTERCEPTION BY A BEECH-PODOCARP-HARDWOOD FOREST NEAR REEFTON, NORTH WESTLAND, NEW ZEALAND

L. K. Rowe*

ABSTRACT

A rainfall interception study was made of a beech-podocarp-hardwood forest near Reefton during the three year period 1 October 1975 to 30 September 1978. Throughfall for the period was 4540 mm, 73% of the 6220 mm gross rainfall. Seasonal variation was evident, mean throughfall for the summer months (October to March) and the winter months (April to September) being 68% and 77% of their respective gross rainfalls. Stemflow was measured for only two years and amounted to 1.5% of the gross rainfall. Interception loss averaged 26% for the whole period, 30% in summer and 21% in winter. Interception storage capacity is estimated to be of the order of 2 mm.

INTRODUCTION

A multiple catchment study was begun by the Forest Research Institute in Tawhai State Forest during 1974 to investigate the hydrological effects of clearfelling and converting indigenous mixed beech forest to *Pinus radiata* plantations. The nature of the study, the description of the catchments and some of the hydrological data collected during the pre-treatment calibration phase have been presented by Pearce *et al.* (1977) and O'Loughlin *et al.* (1978). During the calibration period rainfall interception was studied under the undisturbed beech forest in Catchment 8 (Fig. 1), one of the experimental treatment catchments, to provide a more detailed understanding of the water balance of the undisturbed catchments. Preliminary data from the first year of the interception study are presented by Rowe (1976); the results of the complete study from October 1975 to September 1978 are presented here.

* Forest Research Institute, Christchurch, New Zealand.

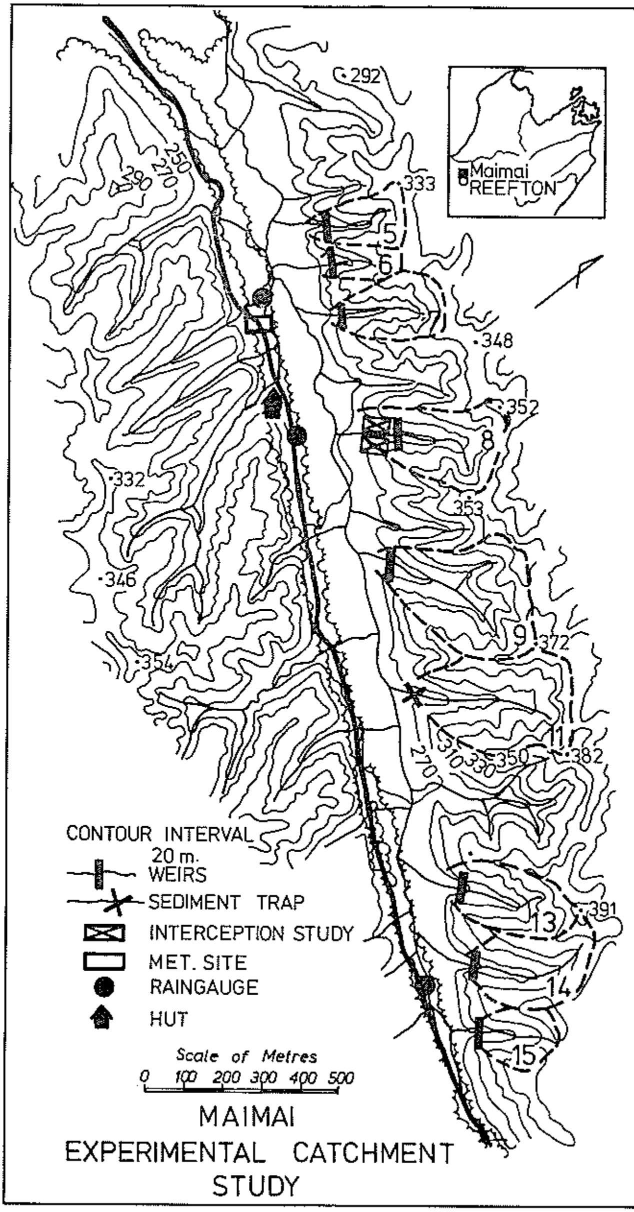

FIG. 1—Location map of study area.

PLOT DESCRIPTION AND EXPERIMENTAL METHODS

The interception study was established in the lower reaches of Catchment 8 about 100 m downstream from a stream gauging weir (Fig. 1). Two opposing slopes were chosen for throughfall and stemflow sampling, one east-facing, one west-facing. Both plots were sited on the mid slopes of the narrow valley about 25 m above the streambed. Details of the plots are given in Table 1.

	True left	True right	Total
Slope, degrees	43°	37°	—
Ground area, m^2	205	140	345
Trough area, m^2	4.818	4.785	9.603
Tree species:			
Nothofagus species	9	7	16
Weinmannia racemosa	30	15	45
Podocarpus ferrugineus	2	0	2
Carpodetus serratus	2	0	2
Total	43	22	65
Tree diameter (measured at breast height)			
2-10 cm	19	7	26
10-20	14	9	23
20-30	6	3	9
30-50	2	2	4
50+	2	1	3

TABLE 1—Site details of rainfall interception plots.

The plots were situated in undisturbed mixed beech, podocarp, hardwood forest with a multistoried structure and variable canopy density, typical of the vegetation cover over the area encompassing the experimental catchments. Vegetation on the throughfall plots consists of beech (*Nothofagus fusca*), hard beech (*N. truncata*), silver beech (*N. menziesii*), kamahi (*Weinmannia racemosa*), miro (*Podocarpus ferrugineus*) and putaputaweta (*Carpodetus serratus*), these being the only species with stems greater than 2 cm in diameter at breast height. Ground cover is generally sparse, consisting of *Blechnum discolor*, pepperwood (*Pseudowintera colorata*), *Dicksonia lanata*, and *Coprosma* species. Top canopy height averages about 25 m.

Gross rainfall

One Lambrecht natural siphon pluviograph was located 200 m to the southwest of the interception plots at the mouth of Catchment 8 in a long and narrow clearing. Five other raingauges were used to check the reliability of the rainfall record. Canopy level gauges were not considered practicable and there were no suitable canopy gaps for ground level gauges.

Throughfall

Previous experience (Rowe, 1975) in sampling throughfall with 127 mm diameter raingauges under mountain beech forest (*N. solandri* var. *cliffortioides*) in Canterbury indicated very high variability in throughfall distribution, e.g., only 9 of 110 storms sampled by 15 randomly located raingauges had coefficients of variation less than 25% while others were as high as 85%. Hence, it was considered preferable to try a trough system in order to integrate some of the expected variation.

On each sampling plot three lengths of 10 cm wide plastic spouting approximately 15 m long were laid out more or less parallel to each other, three to four metres apart, along the contour. The troughs were established approximately 45 cm above ground level, a height which avoided ground splash but allowed the troughs to pass underneath the lowest understorey canopy level. Throughfall collected in the troughs was led off to a bank of five inter-connected 200 *l* drums. The water in these drums was continuously monitored using chart recorders and converted to depth in mm for the plot.

Stemflow

Lead collars, 5-10 mm wide, were sealed to the stems of half the kamahi and all other trees greater than 2 cm in diameter. Stemflow collected was led off into 10 *l* or 20 *l* tins. Measurements were made for 40 of the 65 trees within the interception plots. On six trees, where significant moss and lichen growth capable of dripping outside the lead collars was present, split car tyres were sealed to to the stems below the lead collars to give some indication of drip within an annulus approximately 10 cm wide. Stemflow was measured for individual trees for each storm period. Total stem flow volume collected was then expressed as mm depth over the whole plot, an allowance having been made for those trees not sampled.

Statistical tests

All statistical tests carried out on the data collected for this paper refer to the 95% confidence level. Minor discrepancies sometimes occur in tables and between tables due to rounding off or occasional missing records.

RESULTS AND DISCUSSION

Rainfall

Table 2 summarises the annual data from the Lambrecht pluviograph for the period of the study. Comparative data are available for stations of the Reefton Forest Service (RFS, New Zealand Meteorological Service station F21182) and the Reefton School of Mines (RSM, F21181) approximately 6 km to the southeast, and at Maimai (F21172), 3 km to the southwest of the study site. Normals for these stations are from N.Z. Meteorological Service (1973b).

Monthly variation at the mouth of Catchment 8 has been considerable, ranging from 32 mm (February, 1978) to 317 mm (January, 1976). Corresponding rainfalls at the RSM station were 25 and 254 mm, 18% and 164% of their respective monthly normals. 297 mm fell at Catchment 8 during December 1976. The corresponding rainfall at the RSM station was 294 mm which was 190% of the normal. The driest extended period was February to April 1976 (290 mm at Catchment 8, 210 mm at the RSM station), with a recurrence interval at the RSM station of greater than 10 years (estimated from percentiles in N.Z. Meteorological Service, 1973a). No extended wet periods occurred with estimated recurrence intervals greater than five years.

	Normal	1975-6	% N	1976-7	% N	1977-8	% N	Mean	% N
RSM (mm)	1950	1770	91	1680	86	1630	83	1690	87
RFS (mm)	2020	1810	90	1750	87	1650	82	1730	86
MAIMAI (mm)	2620	—	—	—	—	—	—	—	—
LM (mm)	—	2210	—	1970	—	2070	—	2080	—
LM/RFS %	—	125	—	117	—	127	—	123	—

Data rounded to nearest 10 mm or %
RSM—Reefton School of Mines,
RFS—Reefton Forest Service, LM—Lower Maimai.

TABLE 2—Annual Rainfall.

Daily falls for the period were not high. The highest 9 a.m. to 9 a.m. fall at the RSM station of 73.2 mm had a recurrence interval less than two years; the next highest was only one year. Midnight to midnight falls over 70 mm were recorded at Catchment 8 on six occasions, the highest being 108 mm.

In general, the rainfall regime at Catchment 8 during the study period was lower than normal by about 300-400 mm a year. Although only one gauge was used, this was considered to be representative of the area as comparisons between it and another gauge 1.5 km up Powerline Gully (Upper Maimai) generally show hourly differences of less than 1 mm, daily differences of only a few millimetres, and monthly differences of less than 5%.

Stemflow

Stemflow measurements were taken for the period 3 August 1976 to 25 August 1978. Total stemflow collected by the lead collars amounted to 60 mm. This was only 1.5% of the total rainfall for the period, a proportion similar to that previously reported for mountain beech at 1.3% (Rowe, 1975).

This result is very much lower than that reported for hardwoods in other New Zealand studies. Jackson and Aldridge (1973) measured stemflow from kamahi at 25.3% of gross rainfall. Aldridge and Jackson (1973) had previously reported stemflow from hard beech at 15.4% of gross rainfall. However, because of the differing measurement techniques these results are not directly comparable to those of the present study. In their studies stemflow from 3 kamahi and 14 hard beech trees was collected and related to the canopy projection area of the individual trees. For the present study this was not practical as the canopy is multistoried.

Attempts were made to correlate stemflow for each tree to the size of the tree using diameter at breast height as the indicator of size. Parametric tests, such as Spearman's rank correlation and Olmstead and Tukey's corner test for association, showed no consistently significant correlation between stemflow and aspect or species. The broad scatter of the data indicated that regressions of stemflow quantity on tree diameter were not warranted.

Stemflow collected from individual trees appeared to be dependent on site location and tree form. For example, kamahi were generally multi-stemmed with up to six stems from the one root system. From one three-stemmed kamahi, a stem 7.3 cm in diameter and ranked 17th in size of all sampled kamahi gave the third largest stemflow, whereas another 18.3 cm diameter stem delivered less than half the stemflow of the smaller stem. Factors which also influence stemflow on beech trees are the very rough bark on mature trees and the prolific moss and lichen growth on younger trees. These may have very large storage capacities for holding stemflow. Drip measured in the split tyre collars over the whole period was between 0.6 and 2.8 times the stemflow collected in the lead collar on the same tree. This indicates significant drip occurs close to the stem from drip points on the bark or from the moss and lichens.

Two miro, 34.8 and 14.7 cm in diameter and ranked 6th and 19th in size of all the sampled trees, were ranked 38th and 40th, respectively in total stemflow. Both trees were almost completely covered with moss and lichens on the stems. Drip collected in the split tyre collars was 5.4 and 8.0 times the stemflow in the lead collars.

Throughfall

The large area of interception trough provided a potential for substantial wetting losses. However, these are believed to be negligible. Observations during storms show that movement of water down the troughs to the drums occurs as soon as a very thin film of water forms on the trough surface. Wetting losses seem to be very small as differences between rainfall and throughfall in small storms can be readily explained by filling of the canopy storage and evaporation from this storage at rates similar to those found by Gash (1979) and Rutter (1967). Evaporation from the troughs during storms is likely to be small as the time taken for the troughs to dry after a storm is of the order of twelve hours.

Throughfall for the period totalled 4540 mm, 73% of the 6220 mm of gross rainfall recorded. This is higher than throughfall reported by Aldridge and Jackson (1973) for hard beech at Taita (45.4%), by Miller (1963) also for hard beech at Taita (50-60%), by Rowe (1975) for mountain beech in the Craigieburn Range (69%, summer only), and by Jackson and Aldridge (1973) for kamahi at Taita (45.8%). For a 12 month period the average throughfall was 1510 mm for 2070 mm of rainfall. As the rainfall at Reefton for the period was about 86.5% of normal (Table 2), applying this percentage and using the average throughfall rate measured, in a year of normal rainfall an extra 240 mm of throughfall could be expected. However, assuming that the normal for Maimai is representative of the Powerline Gully area then the additional throughfall in a normal year would be about 400 mm. Hence, depending on the data base, in a normal year throughfall at the study site would be 1750 to 1900 mm.

Table 3 lists throughfall and precipitation for each month of the study. A seasonal effect can be seen as throughfall for the winter months (April to September) tends to be higher than for the summer months (October to March). This is presumably due to lower evaporation rates of intercepted water from canopy storage in winter causing lower interception losses and, hence, higher throughfall. Over the three year period of record winter and summer throughfalls averaged 77% and 68% of their respective gross rainfalls.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Year
1975-6													
R mm	221	160	161	317	43	132	111	243	276	278	144	128	2214
T mm	144	103	99	214	24	90	81	191	201	203	117	101	1563
T %	65	64	61	68	56	68	73	79	73	73	81	75	71
1976-7													
R mm	213	133	313	232	70	153	113	161	266	23	56	205	1938
T mm	154	89	219	167	42	107	81	135	213	15	37	169	1428
T %	72	67	70	72	60	70	72	84	80	66	66	82	74
1977-8													
R mm	148	199	224	73	32	213	82	231	143	268	253	202	2068
T mm	109	121	152	48	21	173	47	206	123	207	204	131	1542
T %	74	61	68	67	64	81	58	86	86	77	81	65	75

TABLE 3—Monthly and annual rainfall (R) and throughfall (T).

Figure 2 shows the storm throughfall as a function of gross rainfall. The results of the linear regression analyses are:

$$T = -(1.51 \pm 0.68) + (0.75 \pm 0.02)\,R \text{ for summer, and}$$
$$T = -(1.60 \pm 0.72) + (0.84 \pm 0.02)\,R \text{ for winter,}$$

where T is throughfall and R is gross rainfall.

A comparison-of-regression test indicated these relationships to be significantly different. A quadratic relationship was tried to see if the fitted curves would pass through the origin. The intercepts were slightly closer to the origin, but the quadratic relationship did not explain any additional variation and was not statistically different from the linear relationships.

Interception loss

Interception loss is almost the complement of throughfall as stemflow is only 1.5% of gross rainfall. Table 4 shows annual interception losses, estimated by assuming stemflow to be 1.5% of gross rainfall. Over the 3 year period interception loss averaged 26% of gross rainfall. Seasonal losses were 30% for summer and 21% for winter. In a normal year interception loss would be approximately 610 mm based on Reefton rainfall normals and 675 mm based on Maimai normals.

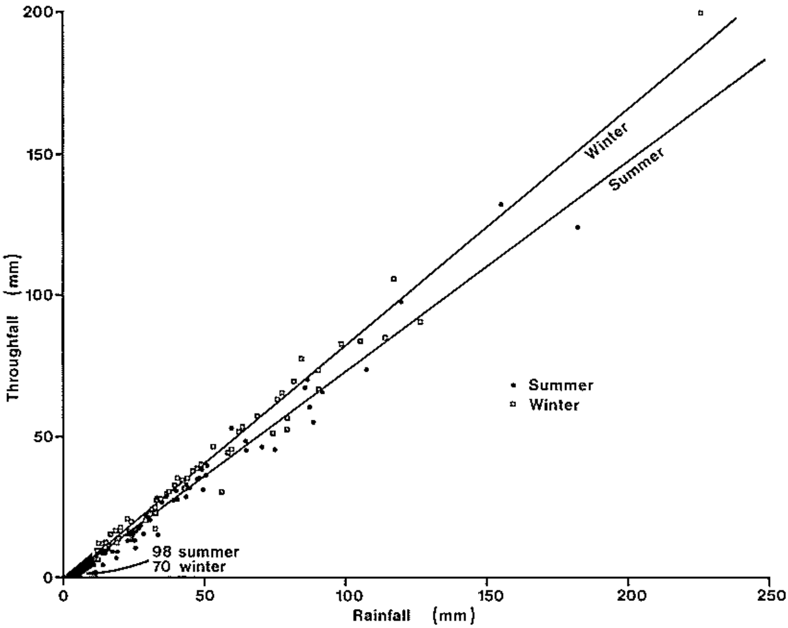

FIG. 2—Throughfall/gross rainfall relationships.

	Rainfall	Through-fall	Stemflow	Net Rainfall	Interception Loss	I/R %
1975-6	2210	1570	30	1600	610	28
1976-7	1940	1430	30	1460	480	25
1977-8	2070	1540	30	1570	500	24
1975-8	6220	4540	90	4630	1590	26

TABLE 4—Interception summary (mm).

Interception Storage Capacity

Interception storage capacity is the amount of rainfall stored on the vegetation canopy that is available for evaporation back to the atmosphere at the end of the storm. One estimate can be found by extrapolating the relationship between throughfall and gross rainfall to find the amount of rain that falls before throughfall begins, i.e. R at T = 0 (Reynolds and Leyton, 1963; Rutter, 1963). If the throughfall rainfall relationship shows curvature at the lower end, then the estimate by this method will be biased. Estimates of interception storage capacity from the regression equations using all data (Figure 2 showed no pronounced curvature) were 2.0 and 1.9 mm for summer and winter, respectively.

Rogerson and Byrnes (1968) took interception storage capacity to be the amount of rainfall that fell before throughfall began. Inspection of throughfall/rainfall data shows that 50 storms of up to 4.1 mm rainfall have occurred with no measurable throughfall. Some of these storms were of very low intensity and considerable evaporation probably occurred. Others were too small for the storage to have filled to capacity. Throughfall has occurred in 24 storms with up to 4.0 mm rainfall. Of 32 storms with $2.0\,mm < R < 4.1\,mm$, the mean of the differences between rainfall and throughfall was 2.0 mm.

CONCLUSION

This study showed that throughfall under a mixed beech-podocarp-hardwood stand was 73% of gross rainfall. Stemflow was 1.5% of gross rainfall. In other words, about 26% of gross rainfall (approximately 675 mm) is returned to the atmosphere directly from the canopy and is not available for soil moisture recharge or streamflow generation. In a high rainfall environment such as North Westland, removal of the forest and consequently of this interception loss could cause streamflow yield increases of more than 600 mm a year in the short term.

ACKNOWLEDGEMENTS

I wish to acknowledge the assistance of the many field staff who helped in the collection of the data.

REFERENCES

Aldridge, R., Jackson, R. J. 1973: Interception of rainfall by hard beech (*Nothofagus truncata*) at Taita, New Zealand. *N.Z. Journal of Science 16:* 185-198.

Gash, J. H. C. 1979: An analytical model of rainfall interception by forests. *Quarterly Journal of the Royal Meteorological Society 105:* 43-55.

Jackson, R. J., Aldridge, R. 1973: Interception of rainfall by kamahi (*Weinmannia racemosa*) at Taita, New Zealand. *N.Z. Journal of Science 16:* 573-590.

Miller, R. B. 1963: Plant nutrients in hard beech. III. The cycling of nutrients. *N.Z. Journal of Science 6:* 388-413.

N.Z. Meteorological Service 1973a. Rainfall percentiles. *N.Z. Meteorological Service Miscellaneous Publication No. 141,* 98 pp.

——— 1973b: Rainfall normals for New Zealand, 1941-1970. *N.Z. Meteorological Service Miscellaneous Publication No. 145,* 34 pp.

O'Loughlin, C. L., Rowe, L. K., Pearce, A. J. 1978: Sediment yields from small forested catchments, North Westland-Nelson, New Zealand. *Journal of Hydrology (N.Z.) 17:* 1-15.

Pearce, A. J., O'Loughlin, C. L., Rowe, L. K. 1977: Hydrologic regime of small, undisturbed beech forest catchments, North Westland. *N.Z. Department of Scientific and Industrial Research Information Series No. 126:* 150-158.

Reynolds, E. R. C., Leyton, L. 1963: Measurement and significance of throughfall in forest stands. In Rutter, A. J., and Whitehead, F. H. (Editors). *The Water Relations of Plants:* 127-141, Blackwell Scientific Publications, London.

Rogerson, T. L., Byrnes, W. R. 1968: Net rainfall under hardwoods and red pine in Central Pennsylvania. *Water Resources Research 4:* 55-57.

Rowe, L. K., 1975: Rainfall interception by mountain beech. *N.Z. Journal of Forestry Science 5:* 45-61.
Rowe, L. K. 1976: Preliminary results from a rainfall interception study under a podocarp/beech/hardwood forest in North Westland, New Zealand. *Proceedings N.Z. Hydrological Society Annual Symposium Rotorua:* 151-164.
Rutter, A. J. 1963: Studies in the water relations of *Pinus sylvestris* in plantation conditions. I. Measurements of rainfall and interception. *Journal of Ecology 51:* 191-203.
——— 1967: An analysis of evaporation from a stand of Scot's Pine. In Sopper, W. E., Lull, H. W. (Editors). *International Symposium on Forest Hydrology:* 403-417, Pergamon Press, Oxford.